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ABSTRACT

This collection of articles address three themes: the growing research supporting the belief that technology in education makes a difference for student learning; innovative ways to use technology in teaching; and firsthand accounts of schools that have successfully implemented technology in their classrooms. Through effective use, educators can implement technology in ways that transform classroom learning activities, enhance idea development and individual expression, promote peer collaboration and problem solving, and foster students' unique learning styles. The collection includes the following articles: "Achieving Technological Equity and Equal Access to the Learning Tools of the 21st Century" (Curman L. Gaines, Willie Johnson, and D. Thomas King); "Linking Students to the Infosphere" (Boris Berenfeld); "Technologies as Tools for Transforming Learning Environments" (Michael Hopkins); "Can Integrated Instructional Technology Transform the Classroom?" (Lani M. Van Dusen and Blaine R. Worthen); "Communication through Multimedia in an Elementary Classroom" (Elizabeth M. Riddle); "Virtual Reality and Multiple Intelligences: Potentials for Higher Education" (Hilary McLellan); "Crossroads to the World" (Dawn L. Morden); "Engaging Students in a Knowledge Society" (Marlene Scardamalia and Carl Bereiter); "The Saturn School of Tomorrow" (David A. Bennett and D. Thomas King); and "It's Elementary! Internet in a K-5 School" (Susan W. Hixson). Contains an index. (Author/SWC)

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TECHNOLOGY in the CLASSROOM

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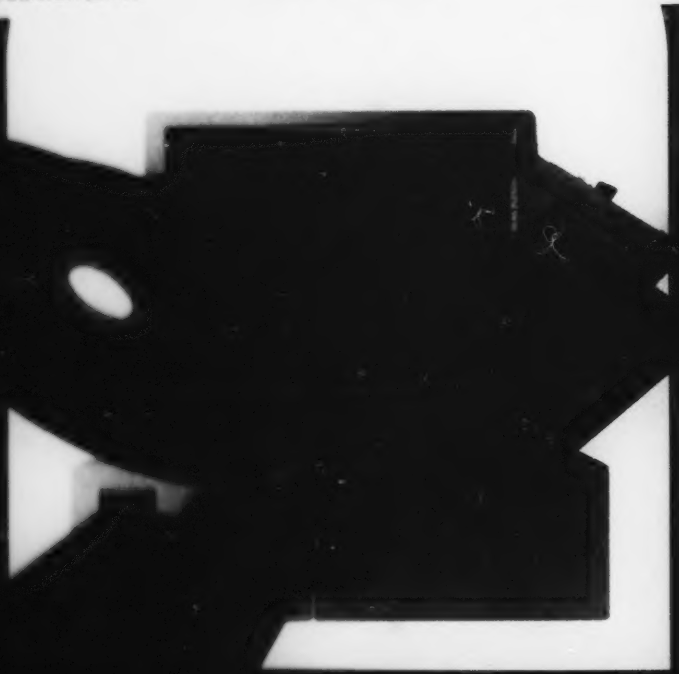

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Technology in the Classroom

A Collection of Articles

Edited by
Tom King

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To the thousands of teachers in America whose daily efforts to secure the learning excellence of each of their students is matched by their own commitment to continued learning and growth.

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Introduction

Technology in the Classroom

I have spent more than twenty years in the exciting area of educational technology. During these years, I have found that while some believe education hasn't changed enough, many think technology is changing far too rapidly. We purchase the latest hardware (and, to some extent, even the newest software), only to find that by the time we get the system up and running, it is obsolete, doesn't do what we'd hoped, or is no longer relevant.

Educators need not only the tools, but also good ideas, sound applications, prudent use, and timely tips. These can be hard to find. This collection offers busy educators a brief compendium of recently published articles on educational technology that have permanence and value. Each article contains important information for teachers, administrators, educational technologists, and teacher trainers.

Among the dozens of publications and journals that deal with different aspects of technology in education, there are hundreds, perhaps thousands, of new articles each year. Educators are busier now than ever before and often don't have enough time to read and research in their areas of interest. With little time, it's hard to know what's worth reading, what might be useful, what new ideas can improve our teaching and our students' learning. Having talked and worked with thousands of educators in recent years, I have noticed recurring themes.

This collection is divided into those themes. Section 1, "The Difference Technology Makes," recognizes the growing research supporting the beliefs of many educators that technology in teaching and learning does make a difference—if used appropriately. Section 2, "Transforming Teaching with Technology," focuses on new ways of using technology in teaching. Finally, Section 3, "Making Technology Work," includes stories of schools that have successfully implemented technology in their classrooms.

There are obviously many fine articles not included in this collection, and it does not cover all of the many topics that well-versed educators need to know. Rather, these articles serve as a springboard for educators' search for information on technology in the classroom. I hope these writings will stimulate thought about these issues and encourage further reading. Most importantly, I hope that readers will discuss what they have learned with their colleagues, students, professors, community members, and other stakeholders in education.

I would be thrilled to hear thoughts about and reactions to these articles and others. My e-mail address is <dtking@stthomas.edu>. Thanks! Good educators always pass it on.

Section 1

The Difference Technology Makes

Technology in teaching and learning makes a difference—if used appropriately. This means teachers need the right kind of hardware to run selected software. It may also mean that training or assistance is needed to get the maximum benefit from its use, whether in the lab or in the classroom.

The first article, "Achieving Technological Equity and Equal Access to the Learning Tools of the Twenty-First Century," is written by three public school administrators (including me, in my former role). The article makes the case that even though school resources are limited, funds must be found (or allocated) to ensure that all students have access to these new tools. And, to assure positive results, teachers must be trained effectively.

As stated in the article, equity of access is not the same as equity of use, nor should it be. Students' needs vary and so does the curriculum. Good use starts with a good technology plan at the site level—a plan that is in accord with district goals, but also addresses the unique needs of the local population, the classroom, and the students' diverse needs. The authors also point out that for technology to work well, help is needed from the community.

Dr. Berenfeld's thought-provoking piece, "Linking Students to the Infosphere," discusses the new realm of the "infosphere" and the importance of electronic networks between and among students all over the globe to do research, create, and share newfound knowledge. Berenfeld reminds us that Internet access requires a new school infrastructure: computer upgrades, local and wide-area network wiring, servers, software, technical support, and training at all levels.

The new "cyberspace" consists of over sixty thousand interconnected networks from all around the world. This plethora of online data contributes to a new dynamic metaphor for learning and for rethinking traditional learning paradigms. The trick is finding what you need in the mass array of data floating in the electronic ether. Berenfeld suggests fascinating Web sites to visit, from Mt. Ruapehu volcano to the International Education and Resource Network (I*EARN). He also discusses tele-mentoring and tele-sharing, moving from online cooperation to "tele-collaboration."

Berenfeld's listing of new pedagogical goals for the millennium forces us to think about technology in new and powerful ways. We need to be ready. Our students are!

Hopkins' article, "Technology as Tools for Transforming Learning Environments," takes a very different look at the computer as a new tool for knowledge. Hopkins was a teacher at the Saturn School of Tomorrow with me back in 1991, when this article was written. We were trying to build a high-tech, high-teach, high-touch school. We succeeded in many ways, but we left many problems to work on for those who followed.

As the lead teacher at the school, Hopkins had the responsibility of leading a skilled team of teachers, parents, community, and, especially, the Saturn School students on this quest of reinventing the notion of school. In his work, Hopkins became increasingly aware of the many ways that students used computers as tools (we had nearly one computer for every two students). He cites the uses as *individualizing learning* (a very common use in many schools); *group interaction* (linking and sharing information with students and the teacher); *managing and coordinating student learning* (Saturn students have a key role in this important task since they manage their own personal learning plans); *expressing or sharing learning*; and *knowledge production* (making new knowledge out of old). Hopkins makes fine observations about the learning process in a new context.

Achieving Technological Equity and Equal Access to the Learning Tools of the 21st Century

by Curman L. Gaines, Willie Johnson, and D. Thomas King

Is there a problem of technology equity in our schools? Just ask the kids and teachers who use it. Even better, ask those who can't access it enough or at all. Technology's new tools are seen as empowering, productive and motivational. They make learning fun; more importantly, they let the user both access and create new realms of knowing and doing. But there simply aren't enough of these learning tools to go around, and many learners are being denied access.

School decision-makers are aware of the critical need for broader technology access. Parents, too, recognize the importance and, those who can, provide it at home. Employers tell us that nearly all workers entering the job market in this next century need to have an expanded set of technical skills in communication, problem-solving and product. Productivity and profit will both be linked to workers' effective uses of new technologies. Many high school graduates can't compete for entry-level technical jobs. Once hired, they're unable to progress to more responsible, remunerative levels of their chosen professions. Inequities of class, gender, ethnicity, and economic disparity correlate highly with denies or restricted access to the tools of technology. The have-nots have increasingly less.

When it comes to gaining greater access, many groups and classes are simply unable. The resources are just not there. Futurists tell us that tomorrow's workers who want to stay employed, or be re-employed, will need the skill of learning new skills. Technology will be the common link among most of tomorrow's jobs. Our growth as a national power has depended largely on the expertise of

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our workers. If our schools fail to pass on these new skills, there may not be another opportunity. Inequity of access to today's new tools becomes tomorrow's enduring societal loss.

THE STATE OF TECHNOLOGY

Students don't have to share pencils. Most teachers even have their own overhead projectors, and certainly their own chalkboards. But when it comes to technology, there clearly isn't enough to go around. Yes, it does cost a lot more than paper and pencils: camcorders and computers are hundreds to thousands of dollars apiece. Most schools don't have the funds to address the issue of adequate access, let alone equity.

We need to remind ourselves, too, that there's more to technology tools than computers.

In Minnesota's Saint Paul Public Schools, there are 13 students to each computer. That's not quite as attractive as the state average of about 16:1 and the national ratio of 11:1. Ratios vary considerably among the 16,000 school districts and, taken alone, don't tell us much about equity of usage, anyway. Many of our district's computers are older, less-powerful machines without high-resolution color, CD-ROMs or Internet access.

We need to remind ourselves, too, that there's more to technology tools than computers. Video tools are smaller and more powerful. New camcorders are hand-held and with editing features formerly found only on more expensive equipment. We find technology permeating new areas, enriching music, art and industrial/vocational education. But, it's not just the number of tools we make available, the number of new features makes a difference, too.

Newer technologies are functionally different from a decade ago. We see far more powerful tools, which let us move from thinking to doing, to modifying, to creating. Knowledge and information are made more accessible to both learners and teachers.

Special needs students are also major beneficiaries of these new tools. For the first time, technology makes learning accessible to many challenged students. While convenience for some learners, technology can be an absolute necessity for others. Instead of adapting our needs to technology, these new tools are better able to adapt to us and our unique learning needs.

EQUITY ISSUES

A recent search disclosed few current articles on the topic of equity and technology. However, Neuman's 1991 article[1] was helpful in clarifying who are the technology "have-nots." Not surprisingly, we find they are most often female, handicapped, minority, disadvantaged and urban. They are the less academically able, more kinesthetic learners, the often "at-risk" students.

Over 95% of homes in America have a VCR, but only 82% currently have a telephone.

Even when we find schools with adequate, up-to-date technology, it is often in the hands of more adept learners. The less able and special needs students are often consigned to less frequent access, to the older equipment, to the redundant, simple software applications.

An amazing statistic we have noted is that over 95% of homes in America have a VCR, but only 82% currently have a telephone. Why the disparity? Videotapes can be fun and entertaining; the phone may be a nuisance to a poor family. Entertainment often wins the battle for scarce discretionary dollars. Still, computers are entering the home at an amazing rate. Nearly one-third of American families are estimated to have computers, and many have CD-ROM-enriched software and modems for access to the Internet. While computer games may be fun, it costs a lot to play. Poor families cannot afford the thousand dollar plus price tags; VCRs and TVs still cost far less.

THE NEW "HIGHWAYS"

We have all heard government leaders declare the need for equal access to the new "Information Highways." When a new technology is first produced, it doesn't mean everyone wants to use it. When the teletype was first hooked up from Maine to California, Mark Twain was said to remark, "What makes you think anyone in Maine wants to talk with anyone in California?" It turned out, of course, that ultimately many did, but broad access still is often an issue of economics.

Governmental regulation or statements of encouragement haven't inspired equity of access. Most schools are funded primarily by local taxes. Urban and rural schools simply do not have the tax base as their suburban counterparts. State and federal government must move to help address this growing inequity of funding for education.

THE NEW SKILLS

Learning *about* computers has changed to learning *with* computers. Programming and simple keyboard literacy have given way to desktop publishing and presentation, digital imaging and robotics, research and referencing, and to exciting new ways for students to demonstrate their learning accomplishments.

In *The Edison Project Report*, Hechinger and Hopkins have characterized this new paradigm of use, calling it "Technology as a Second Language." They describe it as a new process, affording an opportunity to learn many new tools of expression.[2] In their "Three C's" paradigm, just as with language, the user first needs a facility level to be able to "*communicate*" (to simply express one's ideas and needs). Next comes a "*comfort*" level with the newly learned languages of technology. The user now has a greater degree of comfort in being able to express ideas and understanding with facility and variety. Lastly, the learner may progress to the "*creative*" level, where the applications of technology become more unique and artistic, allowing for the freer expression of metaphor and representational symbolisms. Just as we become adept at spoken and written language according to age, need and ability, the same may be true for learning the new language of technology. Once again, it is essential that all students be provided equal opportunities to learn and use these new skills.

HOW TECHNOLOGY REALLY HELPS

There are many ways technology addresses different student needs. Former Saturn Lead Teacher Mike Hopkins has written about these different uses of technology for learning.[3] As staff developed the many new teaching and learning styles at Saturn, they found effective uses for technology in the following ways:

1. As a tool for ***individual learning*** (including skills building, referencing . . .),
2. As a tool for ***group interaction*** (e.g., a technology called Discourse enables the teacher or presenter to view learner responses to questions or problem situations),

3. As a tool for *managing and coordinating learning* (the student's personal growth plan, schedule building, portfolio construction, e-mail writing),
4. As a tool for *expression* (writing across the curriculum, video and multimedia, telecommunication networks),
5. As a tool for *knowledge production* (HyperCard, Hyperstudio and Lego/Logo projects for portfolios, MIDI music and new tools for art).

We are convinced that effective and equitable use of technology leverages school reform. Once students and staff decide to make meaningful uses of technology, learning is never the same again. Technology helps move the act of learning from hearing (and forgetting), from seeing (and remembering), to *doing* (and understanding). It helps bring about the active learning we educators all encourage, but find difficult to do.

Technology helps with different learning styles and provides new ways to learn. Equity requires that we address the learners' needs and learning styles. Thomas Armstrong lists a number of technology-based software systems that address multiple intelligences.[4] Among the intelligences and examples of concomitant software are:

Linguistic: word processing, desktop publishing

Logical-Mathematical: computer programming, Science Tool Kits

Spatial: animation, paint and clipart, Tetris

Kinesthetic: Lego-Logo, Flight Simulator

Musical: MIDI systems, Vocalizer

Interpersonal: Kidsnet, Discourse System

Intrapersonal: career software, decision-making systems

Technology can help address new learning standards that are more authentic, project-based and outcome-driven. Here in Minnesota we are moving to new "Graduation Standards" to replace "seat time standards" and Carnegie units. We are looking to portfolios and performance, in addition to report cards and GPAs. It is our belief that any activity as rich and complex as human performance must be addressed in a broader context than report cards. Numerical and letter grades are inadequate in describing what young learners know and can do. Perpetuating this process cheats the learner and the community.

OTHER TECHNOLOGIES

Many teachers and students have discovered the power of video and the visual medium in the learning process. Students with a camcorder in hand and some rudimentary instruction can "show and tell" wonderful projects about what they've learned. Video, perhaps even more than the computer, is the new medium of expression with today's generation.

Video is the new medium of expression with today's generation.

We have seen many students construct marvelous video scenarios, creative stories and cooperative projects, showing remarkable production sophistication. The digital format makes it easier to marry the messages of these media together in very powerful presentational ways.

One day soon the Internet may provide a huge "electronic kiosk" of student performances (as do some Web pages already), and help learners improve what they know and can do. By exhibiting their work electronically, and by inviting comment and criticism from others, students can hone their knowledge.

LEVERAGING LEARNING REFORM

Our district chose early entry into the "school reform through technology" arena. We designed and introduced the innovative Saturn School of Tomorrow project back in the late 1980s and became one of the first school districts in the country to commit major resources and collaborative efforts to school reform.

Saturn's design called for equity of access to technology for all students in the school, as a part of the school's "high-touch, high-teach and high-tech" mission. We have since witnessed many successes in student accomplishment and learning. Once technology is integrated into the curriculum, and students are doing "real" learning activities, it's often impossible to return to simple lecture and listen as a means to "learning."

Teacher behaviors will change, too. Staff development is essential, not just for the new technology, but also for the new ways that teaching and learning will happen.

President Bush came to visit and recognize the Saturn School in 1991 in announcing his America 2000 (now Goals 2000) initiative. One thing our students taught him, and the thousands of other visitors over the years, is that powerful learning can happen with technology. Many are amazed at what these students do with desktop publishing, MIDI synthesizers, HyperCard, Lego/Logo, and video cameras.

But the staff have had to find ways to assure that other, more traditional learning is happening, too. Saturn students take the same national, standardized and district tests that others do and must show acceptable performance.

NEW PLACES AND SPACES FOR LEARNING

It should come as no surprise that better access to technology-transformed learning activities means redesigned learning environments.

Our District-Wide Technology Plan calls for moving more of our computers from labs into the classrooms. If we want our teachers to integrate technology into our teaching, it must be readily available. Further, they must know how to use it and what their students can do with it. Broader staff training has allowed us to change our old computer lab paradigm. New designs call for lab technology stations, with many kinds of technology tools for exploration, simulations, construction and testing. Often, there's more "noise" from students and their new tools, but there's also more real learning, too. The older lab computers are being moved to the classrooms for report writing and special learning and knowledge production uses. Networking, both local and wide area, is also an item of equity concern, as we look at many schools and a limited budget. We do not believe every classroom must be wired for communications. Cellular communications will obviate some of the needed writing, particularly when there is not continuing need for a network in a given space.

ADDRESSING INEQUITIES FOR LEARNING IN THE HOME

We are trying to find relatively inexpensive technologies that we can let students take home and use. Older Apple IIs, for example, can be assigned for home use, for special projects or for students with special needs. Some manufacturers are making special purpose, low cost, limited-function computers in the ($200–$400 range) that students can sign out without the worry of thousand dollar replacement costs. We await lower cost clones, particularly laptops that we can assign and reassign easily to students and staff.

We need manufacturers to "modularize" their computers so we can more simply replace certain components (CPU components, drives, CD-ROMs, monitors, etc.) without replacing everything. We think that technology must eventually be seen as a utility or service for which districts pay might pay an annual fee to assure appropriate access for all students. That service could include needed replacements and repair, even the training and retraining of staff and students.

A PLAN FOR CHANGE AND FOR SUCCESS

One of the most frequent questions we get from our schools is, "Where is our new technology?" Our response has been, "Where is your plan?" Fortunately we have a district-wide Technology Plan which serves as a basis for each school's site plan.[5] Each school develops a plan in accord with our board-adopted goals. All site planning ties back to the district's Strategic Plan, and that focuses everyone directly on increasing student achievement (which is a singularly important goal). Our Superintendent has stated our mission-building process in a terse and pithy five-step way: "Dreaming It; Planning It; Doing It; Changing It and Proving It!" That last accountability component is crucial, especially if we include "equity of access" among our requirements. If we can't show that improved student achievement is working, then our response is, "Why are we doing it?" We must find a way to make it work.

Another initiative that addresses the "tech-entity" issue for us is our "97 by '97 Project." As a part of our "High Five" strategic planning, we are focusing intensively on five key learning areas. The top two are: higher student achievement for all students, and a higher graduation rate for all students. That latter goal has been re-stated as "97 by '97." We are working to improve our graduate rate to 97%

by 1997. That's a truly ambitious goal as our current graduation rate is now about 82%. We want to develop a new model that is fast-tracked and tells us what will work. We know many at-risk students rarely have access to effective learning technologies. Technology plays a major role in this project by providing a software-driven personal plan for each at-risk student. It also assists with skills development, off-site learning and an electronic "mentor-net" of advocates and other helpers for at-risk learners. We believe we must do a better job of using technology, in particular, to help students who haven't learned well in traditional settings.

Accountability is a critical part of our technology planning process.

TECHNOLOGY AND EVALUATION

Accountability is a critical part of our technology planning process. It affects equity concerns, too. With scarce resources, we must find ways to know if our initiatives are working at all levels. Often, we hear the question: "How do you know if your use of technology is cost-effective?" One may be tempted to respond, "How do you know what you're doing right now is cost-effective?" While the retort may be valid, our challenge is to find comprehensive baseline standards that allow us the accountability that's needed to proceed.

Both current and planned technology applications need the same level of scrutiny when it comes to learning success. Questions we ask are: "Is there any visible evidence of comprehensively improved performance? Attendance? Level of engagement? Are we addressing learning styles? Are students working effectively individually and/or cooperatively? Do they show improved expression, communication, or creativity?

If technology isn't working equitably and effectively at a site, we intend to find a way to make it work. It simply does not make good sense to put into schools expensive technologies that are not being used effectively. A technology plan, which includes staff training and frequent assessment, is critical to success.

WHERE CAN WE FIND THE FUNDING?

Equity requires that we rethink the way we look at and use the resources we have now. In Saint Paul, for example, we have redirected a major part of our textbook budget to purchase new technology. Today's CD-ROMs can and should replace some of the outdated printed materials, particularly reference materials or out-of-date textbooks. We are asking our school sites if they wish to spend some of their allocated funds differently. More directly put, "What are you willing to give up or trade for more technology dollars?" Priorities change and so must the budgets that go with them.

We educators ought to have a "Socratic oath" that commits us to the goal of every single student becoming a successful learner.

We are looking into technology leasing options from our operating funds, in addition to the capital equipment dollars we spend now. More flexibility must be found in the way we spend our funds. District-wide software licensing has saved us money over licensing at the building level.

Most of all, however, we need new funding sources if "tech-equity" is to happen. Without a major overhaul of the educational delivery system, including reallocation of existing dollars elsewhere, the only other alternative is massive state and federal assistance. If railways and interstates were such a federal/state funding priority this past century, it is hard for us educators to imagine that the electronic "highways for learning" are any less important.

A STORY AND A SUMMARY

It's a part of the time-honored American dream that we provide educational opportunity for *all* our students. That's not enough anymore. We've got to secure the education of *each* student. Equity requires that we assure both adequate opportunities and resources for each and every student we serve. We educators ought to have a "Socratic oath" that commits us to the goal of every single student becoming a successful learner.

Not all students will learn at the same level or in the same ways. While a basic level of understanding is important for everyone, each must be encouraged to seek the mastery levels that their unique talents and goals allow. Equity of access, we would stress, is not the same as equity of results. We must all be pledged to equity of access and resources; our students must be pledged to secure their own, best results.

Our abiding hope is to turn our students into "teachers" within their own learning communities, near and far. Unless the learner can explain his new-found knowledge, he or she does not truly "own" it.

One of our young students got the chance to show President Bush his computer project during the President's visit to our Saturn School of Tomorrow. Although he was clearly getting better at his learning, he was not yet an accomplished student. But his Lego/Logo robotics project had been well done and was a key part of his Personal Learning Plan. When the President asked him what he liked about computers, he paused for a while. "I'm still improving on my reading and writing, but I've always been much better with my hands," he said, "and computers let me work with my hands."

That was a great message for the President to hear: technology helping out with a student's unique learning style, one that shows that different students need different resources. Even the President needs to know that. More importantly, so do the elected and the electorate. We hope that others will help us address the learning needs of each student and share with us the goal of assuring that there truly is equal access to the learning tools of the 21st century.

NOTES

1. Neuman, Delia (1991), "Beyond the Chip: A Model for Fostering Equity," *School Library Media Quarterly*, 18, pp. 158–64.

2. Hechinger, Nancy & J. Michael Hopkins, remarks at the 1995 AASA Convention, New Orleans, La.

3. Hopkins, J. Michael (April, 1991), "Technology as Tools for Transforming Learning Environments," *The Computing Teacher*.

4. Armstrong, Thomas (1994) "Multiple Intelligences in the Classroom," *ASCD Yearbook*, p. 160.

5. Bennett, David A. & Thomas D. King (May 1991), "The Saturn School of Tomorrow," *Educational Leadership*.

Linking Students to the Infosphere

by Dr. Boris Berenfeld

For educators, the infosphere forces a rethinking of traditional learning paradigms.

A driving principle of the recent Telecommunications Reform Act of 1996 is that "schools and classrooms . . . should have access to advanced telecommunications services."[1] In light of the media attention focused on the Internet and school connectivity, this call sounds reasonable and worthwhile. But exactly what are "advanced telecommunications services" and how will they impact education?

Over the last decade, the dominant mode of telecommunications in schools has been e-mail exchanges between classes.[2] Even though messages were limited to non-graphical ASCII text, the ability for one class to easily and cheaply communicate with either another or many through the world was so powerful that educators developed a number of successful learning projects around e-mail. Yet today, e-mail hardly qualifies as advanced telecommunications. At the core of advanced connectivity lies access to the Internet's sophisticated capabilities.

Providing universal Internet access to schools in a way that benefits daily instruction demands a considerable investment in hardware and infrastructure. School administrators can no longer isolate computers in computer labs, but must make them accessible to all venues of learning on a school's premises, and these machines must be capable of handling both multimedia and large files. They must consider computer upgrades, Internet providers, ongoing technical

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support and even school-wide local area networks. Many schools need to be rewired, which often involves costly retrofitting. Teachers must learn to operate the hardware as well as how to integrate connectivity into their practices. Furthermore, educators should infuse networked learning into school culture.

"When we've got leaky roofs, filling a room with technology seems stupid."

After all the wires have been laid, the computers connected and turned on, and the teachers trained, will the students be ready for Internet access? The Internet is unfamiliar terrain that can be challenging to traverse, and there are accepted standards of online behavior, as there are in daily life. Just as students must know the rules of the road when they drive, so must they acquire information literacy and ethics in order to navigate the Internet usefully and responsibly.

Clearly, advanced classroom connectivity requires a greater and more enduring commitment than many may have anticipated. No one, not even policy-makers, know for sure how many tens of billions of dollars this effort will cost or, for that matter, exactly where all the money will come from.

At a time when education is already besieged by other needs, can we justify spending billions of dollars to link classrooms for advanced telecommunication services? "When we've got leaky roofs, filling a room with technology seems stupid," asserted a lobbyist for the California School Board Association.[3] Should a school use its meager resources to fix its leaky roof or purchase new computers and connect them to the Internet?

THE NEW INFORMATION ENVIRONMENT

Physically, the Internet is a vast array of interconnected networks (about 60,000 as of July, 1995) that use the same TCP/IP protocol and evolved from ARPANET. The networks themselves are comprised of many millions of computer interconnected via phone lines, satellite links, fiber-optic cable, etc.

The Internet is a truly unique human creation, and it defies facile description. Consequently, despite the current publicity, the Internet is poorly understood by the public. In order to convey a sense of this vast digital grid, observers have relied on a number of metaphors. These metaphors, however, address only certain features of the online domain. We should ask whether or not these terms sufficiently communicate to policy-makers the sweeping potential that the Internet offers.

A popular metaphor is "cyberspace," which its creator, writer William Gibson, defined as a "consensual hallucination of visually realized data achieved through plugging into a global computer network"[4] (see also: ee.oulu.fi/~thefinn/gibson/gibson/html). This metaphor united our perceptions of cybernetics and physical or outer space. The public has been informed that cyberspace is populated by virtual communities, online discussion groups, "town meetings" and even "electronic pubs." Although intriguing, cyberspace is an exotic phrase that perhaps best serves science fiction, from whence it came. It conjures up a world apart and different from our physical world, one that is unfettered, largely uncharted and perhaps not entirely safe.

The "information superhighway" suggests infrastructure in which information travels over electronic highways, much as cars and trucks negotiate interstate highways. It invokes images of speeding trucks hauling large loads of data in heavy traffic, not of a friendly place where parents would want their children to play.

The "electronic marketplace" implies a domain for transactions of goods and services. This metaphor, however, raises such issues as commercialization, security and fraud. Connectivity offers far more than digital shopping malls.

One interesting description is the "Information Age," for it describes not the Internet itself, which is hardware, but its currency information. The term characterizes the enormous growth of information sources and the convergence of all mass media into one omnipresent, all-inclusive electronic medium. At the core of the Information Age, uniting all information and data resources, will be computer-mediated communications (CMC). Information Age implies a time for a revolution in the information environment.

THE BIOSPHERE AND THE INFOSPHERE

For an appropriate analogy to grasp the new information environment as a cohesive and integrated flow of knowledge, let us consider the concept of the "biosphere," a term coined in the beginning of this century by Russian geochemist Vladimir Vernadsky to describe the "envelope of life" as an interdependent planetary web.[5] The concept, in effect, summarized all that was known in the natural sciences and asserted the unity of life and the space it inhabited.

Similarly, the information environment needs a metaphor that implies the growing unity, interdependence and accessibility of information produced by humankind and to this end, this paper proposes the infosphere.

The infosphere summarizes advances in nearly all human endeavors. Technologically, the infosphere traces back to the telegraph and radio, the first computers and monitors, and the Internet and the World Wide Web. Yet with its far-reaching global impact, the infosphere is also the product of political and cultural change. Sputnik, manned lunar landings, and the first photograph of the entire Earth—a fragile blue orb in space—encouraged all people to think globally. The collapse of the Berlin Wall broke down many political barriers to the infosphere, and the widespread adaptation of telecommunications technologies by science and commerce nurtured the infosphere at its birth.

The infosphere summarizes advances in nearly all human endeavors.

Each prior advance in communications—paper and ink, the telegraph, the radio, the telephone and television—deeply changed society. The infosphere encompasses all these media as well as such new ones as computer-mediated communication, computer simulations and virtual reality. Its impact on society promises to be profound. Already, this new communications environment is becoming increasingly dynamic as more and more users not only access the plethora of online data, but contribute to it as well.[6] For educators, this revolutionary flow of information forces a rethinking of traditional learning paradigms.

This paper attempts to identify the features of the infosphere that have proved to be of educational value. It outlines the basic trends in their adaptation into instructional practice and concludes with the rationales educators use in making their choices.

WHAT THE INFOSPHERE OFFERS CLASSROOMS

Due to the latest developments in Internet technologies, especially for the World Wide Web, we are seeing an explosive growth of the infosphere. As is often the case in the early stages of rapidly growing systems, the infosphere appears chaotic, unstructured and even somewhat frightening. This is reflected in the current debates over restricted access and censorship issues. In light of parental concerns and the high costs to establish classroom connectiviy, a question must be asked: is there anything useful besides sending e-mail and accessing databases that can help teachers teach and students learn? Do we have any evidence that bringing classrooms to the infosphere can justify the great effort that doing so will take?

Tele-access is the use of online resources in learning.

Examination of available online resources and classroom usage reveals five general educational functionalities of the infosphere. They are presented below in ascending order of pedagogical sophistication and potential impact on student learning and school change.

Tele-access

Tele-access is the use of online resources in learning, including outline libraries, databases, museums, satellite data and other classrooms. The latest space shuttle photos (shuttle.nasa.gov/), paintings inspired by Shakespeare plays (www.cc.emory.edu/ENGLISH/classes/Shakespear_Illustrated/Shakespeare.html), pending Congressional legislation (www.access.gpo.gov), or foreign language resources for 40 languages (www.cc.utah.edu/~coj6886/jltc.html) are available to students via the Internet.

In order to complete an assignment, for example, a student might have to access information on Thomas, the U. S. Congress' Web site (thomas.loc.gov/) or download images and maps of the Civil War (www.magibox.net/~civilwar/gallery.html).

When students conduct online searches, they are tapping into information that is real-world oriented and nearly unlimited. Rather than digesting precanned answers, they are constructing their own knowledge and they can do so with equal facility at home and in class.

Virtual publishing

For the first time in history, the ability to publish no longer depends upon owning a printing press. Once the province of scholars and large companies, publishing is now an option for classrooms by means of virtual publishing on the World Wide Web. Virtual publishing can authenticate learning by setting students' scholarship in the real world. Students derive a sense of self-worth when they can claim ownership of work that reaches an audience beyond the classroom, and they tend to invest more effort into work that is to be widely distributed.

Tele-presence enables students to experience events at remote sites.

In the Writers in Electronic Residence project, students publish their poetry for feedback from their peers throughout the world.[10] On the networks supported by Global Schoolhouse (gsn.org/) and International Education and Resource Network (I*EARN) (www.iern.org/iearn) students from different countries publish results of their collaborative projects, including news magazines, literary journals, environmental and human-rights newsletters.

Virtual publishing is hardly limited to text documents. Students can include graphics, video, sound, and animation in their publications, as well as the hypertext links of digital books. Soon, students will even be able to tele-broadcast live sounds, film and video to each other.

Tele-presence

Tele-presence enables students to experience events at remote sites. Students near an ecological disaster or in the path of a hurricane can serve as eyewitnesses for their peers by issuing first-hand accounts, or students can collect data from remote probes, whether the probes be on school grounds or on the moon.

When used with video technologies, CMC allows students to actually see and hear events as they happen remotely. Classes can journey on real expeditions, participate in real experiments and, in effect, "look over the shoulders" of working scientists.

For example, students in The JASON Project remotely explored the ocean floor from their classrooms through a robot operated by the Woods Hole Oceanographic Institute (seawifs.gsfc.nasa.gov/JASON/HTML/JASON.html). In the "Live from Antarctica" project (quest.arc.nasa.gov/livefrom/livefr), students accessed scientists' diaries and field journals to learn how they "lived, worked and played" at the South Pole.

Tele-mentoring

With telecommunications, mentoring becomes a rich and viable teaching option. Many sites on the Internet, such as professional groups and bulletin boards, are responsive to student inquiries. By serving as mentors, scientists and scholars can answer questions and provide classrooms with resources beyond textbooks and the individual teacher's expertise.

A retired engineer, for example, could mentor students at a Harlem high school or an MIT graduate student in mathematics could work with students in Montana.

An example of the tele-mentoring is the online Ask-A-Geologist program sponsored by the U. S. Department of the Interior (walrus.wr.usgs.gov/docks/ask-a-) in which students ask questions of professional geologists. In its first year, the project answered over 3,000 questions.

Though generally associated with teacher development and adult education,[7,8] tele-courses are a variation of the tele-mentoring and are currently in development for K–12 students.[9] Tele-courses can expand school's educational opportunities and are a potentially powerful strategy for advanced, remedial and home instruction. Exposing them to experts, scholars, and people of achievement, telementoring provides students with positive role models. Such relationships can reward not only students but the mentors as well.

Tele-sharing

In their totality, the various functionalities of the infosphere enable students to share all forms of information in a variety of ways. Telesharing often begins with simple e-mail chats between "keypals." It advances to "one-to-many" and "many-to-many" communications, and then blossoms into the sharing of resources, ideas, experiences, data and findings.

This transition from simple communications to cooperative learning offers relevancy and the analytical challenge of comparative studies. Further, it calls upon students to engage in deeper social interactions. Such learning implies an equality among participants rather than the traditional vertically structured, teacher-student relationship.

In Project Investigate, developed by TERC in cooperation with the National Geographic Society, networked students proposed interesting ideas for investigation. If an idea was accepted by other students, the proposing student became the research director for the project while the others provided support and collected data. The project leader, in turn, might have worked for other students by contributing data to their projects.

The Kids as Global Scientists project (stripe.colorado.edu/~kgshtml/Home.html) combines downloading and examining weather data (tele-access) with questioning scientists about their findings (tele-mentoring).

Presently, the most ambitious tele-cooperative project is Global Learning and Observations to Benefit the Environment (GLOBE) (www.globe.gov), which was initiated by the office of the Vice President of the United States, the National Science Foundation (NSF), the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the State Department, and the Department of Education. The program forges a partnership among students worldwide and leading scientists to monitor key environmental parameters. Students transmit their findings to a globe database, a rich resource for comparative analyses for environmental scientists and students' learning.

Tele-collaboration is one of the most sophisticated deployments of classroom telecommunications.

FROM ONLINE COOPERATION TO TELE-COLLABORATION

Tele-collaboration is one of the most sophisticated deployments of classroom telecommunications. It advances online cooperation to distributed problem-solving, collaborative design and cross-classroom, collaborative inquiry. Although collaborative problem-solving offers the most beneficial educational opportunities, Harris noted that "educational problem-solving projects are, as yet, the least common kind of Internet-based activity that involves precollege students."[10]

Though tele-collaborations are a relatively new implementation of classroom telecommunications, teachers have initiated an increasing number of interesting online projects. These teachers developed promising ideas, posted them on networks to recruit collaborators and eventually implemented them.

One of the first large-scale tele-collaborative projects was The InterCultural Learning Network, which started as a collaboration between classes in Alaska and San Diego to produce a newspaper called *The Computer Chronicles.* [11] It culminated in an expanded network in which K–12 teachers, students and college faculty in the United States, Mexico, Japan and Israel engaged in joint newspaper-writing activities. Students from different cultures used each other "as resources for learning more about themselves and the social, cultural, and physical world." [12] In the Global River Environmental Education Network (igc.apc.org/green/) students involved in water-quality study collaboratively explore specific watersheds.

Tele-collaboration goes beyond the sharing of data. In The Global Laboratory Project (hub.terc.edu/gl/global-lab.html), an international, telecommunication-based project developed by TERC with support from the NSF, students investigated local and global environments. After sharing their findings on a project-wide database, students collaboratively identified environmental phenomena, discussed research plans, and together conducted distributed investigations using the same protocols, methodologies, standards and tools. One of the students' discoveries was a dramatic rise of carbon dioxide levels in their classrooms over the course of a school day. One class even managed to persuade its school's administration to replace the ventilation system.[13]

Though tele-collaborative projects require careful preparations in order to standardize and synchronize activities among participating classrooms, they increase the authenticity and relevancy of environments and offer important benefits for all disciplines. They enable classes to conduct distributed research and experiments, thus replicating the processes of scientists and scholars. Participating students must follow uniform procedures, yet the diversity of the data enables them to place their findings into regional, national, and global contexts.[14]

Table 1 proposes how functionalities offered by the emerging infosphere can change the organization of instructional settings, teachers' role, and the flow of information, not only to students but, remarkably, from them as well.

PATTERNS OF CLASSROOM IMPLEMENTATIONS

How do these educational functionalities of the infosphere find their way into classrooms? An accurate picture is difficult to come by because the more advanced functionalities require high-quality connectivity, which are in short supply among many schools. Whereas some schools enjoy powerful computers and high-bandwidth connectivity to the Internet in every classroom, others have obsolete computers relegated to computer labs. In addition, there are great discrepancies in teachers' expertise and experiences; some navigate the Internet effortlessly while others struggle to get online during lunch.

Though presently there is only limited research into how advanced online functionalities are adapted into classrooms, the following patterns have become discernible.

Beginner Pattern: From Extracurricular Use to Curricular Augmentation

Often, telecommunication-based activities are introduced into school life first in extracurricular activities, then, after an exploratory trial period in which teachers gain experience in instructional telecomputing, they are brought into formal classroom courses.

The easiest way to introduce telecommunications into formal courses is through a practice called telecommunications-augmented curricula in which teachers supplement their existing curriculum with online activities. A science class could augment its astronomy curriculum by downloading the latest images from the Hubble telescope or a sociology class could supplement its studies by accessing population figures from the U.S. Census Bureau. A literature class could discuss a book with its author or virtually publish its poetry.

Teachers need not revamp either their curricular or their teaching practices to augment courses with telecommunications. Although the overall teaching strategy remains conventional—teacher and textbook-centered—students now have routine access to online resources and are exposed to an array of additional sources of information and opinions that demand their critical thinking.

Intermediate Pattern: Augmentation to Added-on Telecommunication-based Curricular Inserts

Teachers who successfully augmented their curricula with various online functionalities take the next step in inserting specially designed telecommunication-based curriculum modules into traditional courses. Worldwide, thousands of elementary school teachers insert modules from NGS Kids Network, jointly developed by TERC and the National Geographic Society, into their traditional instructions.[15] Middle and high school teachers involved in the Global Lab project use specially designed tele-collaborative curriculum units as inserts into regular earth science, biology, physics, chemistry, and environmental science courses.[16] Teachers implement the Global Lab units generally one a day week on a part-time basis.

There are diverse reasons for this transitional implementation pattern. Insufficient or inadequate access to the Internet may limit the levels of connectivity that teachers can offer. Also, there is a dearth of full-course curricula designed to fully implement advanced telecommunications features. In addition, many teachers lack the training, experience or confidence to abandon conventional teaching practices in favor of new and unfamiliar ones.

Advanced Pattern: Telecommunication Features Fully Integrated into Curricula

In Telecommunications-integrated curricula, the infosphere becomes integral to classroom instruction. The curricula are designed to fully exploit its advanced functionalities and information flows both to and from students. Learning becomes less dependent on the centrality of teachers, and the teacher's role transforms from the traditional "sage on the stage" to the "guide on the side."

Clearly, teachers find using CMC in daily instruction more challenging than merely downloading files or sending e-mail for extracurricular activities. Full integration requires that schools, in addition to giving students sufficient telecommunications access, must redefine their pedagogical goals, restructure curricular offerings, provide teachers with training and support materials, and obtain tools for students' collaborative data collections. Often teacher-inspired grassroot efforts lack the resources to provide the support and curricular framework that telecommunication-based curricula demands.

The NSF, federal and state government agencies, and non-profit research groups have developed a number of large-scale test-bed and demonstration projects[17, 18] to encourage and support schools' efforts to advance their classroom implementations.

The Testbed for Telecollaboration (teaparty.terc.edu), organized through TERC and funded by the NSF, explores the impact of telecommunications technology on teaching and learning. Numerous studies describe how progressive integration of CMC into curricula transforms traditional, teacher- and textbook-centered classrooms into real world-oriented student communities of practice.[19, 20, 21, 22, 23]

NEW LEARNING ENVIRONMENT BEGETS A NEW LEARNING PARADIGM

A common rationale for linking classrooms is to prepare students for future work. Indeed, we see increasing demand for "knowledge workers" versed in telecommunications, but the workplace of the near future will not demand the mechanical skills of turning on a computer and modem; as technologies advance, getting online may be no more difficult than using a telephone.

The emerging infosphere is changing how we work and how we find, access, analyze, process, and exchange information. These information access and management skills, as well as the ability to critically evaluate information, are what students will need to ensure their competitiveness in the workplace of tomorrow.

Telecommunications expand the learning context by bringing the real world into the classroom.

Yet linking students to the infosphere will do more than prepare them to compete in twenty-first century economies. Educators are increasingly relying on telecommunications to comply with new reform standards. The literature reveals many common rationales for using the infosphere to meet advanced pedagogical goals. The ones most frequently cited are:

- *Bringing real-world relevance into the classroom.* Ironically, schooling, which is said to prepare students for life in the real world, is tremendously isolated. Learning is compartmentalized behind closed doors. Telecommunications expand the learning context by bringing the real world into the classroom. Students and teachers can establish interactive connections with anybody or any source, making learning more relevant to their lives, interests and concerns.
- *Helping students perceive knowledge as constructed.* When linked to the infosphere, students can access an astounding array of data

and human resources, and this turns learning into a dynamic process. They can develop a more accurate view of the scientific community. They can actively participate in their learning and engage in open-ended construction of new knowledge.

- *Providing students with an effective model of lifelong learning.* When students research vast arrays of multimedia information, apply credibility tests to access what they find, and learn telecommunication techniques such as the "art" of World Wide Web publishing, they will develop skills they can rely on for the rest of their lives.
- *Bolstering social, communication and critical-thinking skills.* Students can enhance their communication, social and collaborative skills as they interact and learn with other classrooms or online mentors. They also will ply their critical-thinking skills when called upon to collaboratively solve problems and perform analyses via telecommunications.
- *Meeting emerging standards for inquiry-based learning.* Though there is a widespread call for project-based learning, even innovative teachers struggle to implement student investigations. CMC can powerfully enhance inquiry-based learning by enabling teachers either to join ongoing projects or to develop their own.
- *Increasing the authenticity of the learning environment.* By directing students to access such resources as rare historical archives, eyewitness reports or digital museums, teachers increase the authenticity of the learning environment. Telecommunications create enhanced pedagogical settings in which students can communicate, cooperate, conduct distributed experiments and build upon each other's knowledge. In this context, students are learning in the real world like adults.
- *Putting a human face on learning.* Using online resources, teachers put a human face on many aspects of learning, whether it be communicating with other classrooms or with experts who serve as mentors.
- *Finding role models for students.* By electronically bringing professionals, scholars, explorers, educators, writers, poets, and scientists into classrooms, teachers expose students to positive role models.
- *Equity.* The infosphere offers a vast palette of learning resources that would be beyond the means of even the wealthiest schools to obtain any other way. When online, all schools are on an equal footing in their ability to access the same resources.

FINAL THOUGHTS

In summary, the impact of today's telecommunications revolution on schools goes vastly beyond replacing the old blackboard with a shiny whiteboard. The infosphere is revolutionizing the very nature and dynamics of the conventional classroom experience; this new learning environment, by design, emphasizes students' autonomy and independence.

Classroom learning will become student-driven, interactive, experiential, and collaborative—all goals long-cherished by many educators but never before attainable. Students will no longer passively receive information but will manage and synthesize it and even contribute to the infosphere.

They become not only takers, but "givers," or creators, of information. Giving can include reporting events, sharing observations and findings, contributing ideas for future projects and conducting peer review. This level of interaction will herald new types of student communities of practice. In this innovative paradigm, students' ability to contribute to the infosphere will be integral to their learning.

Furthermore, education will not be confined to dedicated locales known at schools during specific periods of an individual's life, a model that dates back to the ancient Sumerians; learning will be lifelong and always accessible.

For the first time, we can truly prepare generations of students for the future. And also for the first time, students will benefit from the newest technologies rather than be the last to use them. Students can follow the latest advances in all learning domains as they occur, rather than read about them a decade later in textbooks.

Providing each student with high-quality access to the infosphere will undoubtedly meet with resistance because of the costs and issues involved. Yet one is reminded of the words of Alvin Toffler, author of *Future Shock and Third Wave:* "If education has any function, any justification, it is to prepare young people for the future."[24]

It is true that some roofs leak, but educators, policy-makers, parents and everyone else with a stake in the well-being of society must realize that the new millennium promises advances greater than ever imagined. The groundwork for these opportunities must be laid in our schools today.

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Technologies as Tools for Transforming Learning Environments

by Michael Hopkins

In this rapidly changing world, educators cannot simply react to the present, we must prepare children to live in the dynamic, unpredictable world of the future. A few years ago, Al Shanker challenged St. Paul educators to follow the lead of General Motors, and develop a "Saturn" school, a new vision of education that uses the best methods and processes of existing schools and the most powerful and useful emerging technologies. The Saturn School of Tomorrow is the St. Paul Public School's most unique attempt to prepare learners for living in and creating the future.

Saturn opened in temporary quarters in September of 1989, serving 160 fourth, fifth, and sixth graders. This fall the school added seventh grade and increased enrollment to 220 students. Next year eighth grade will be added and enrollment will increase to 300 students. While involved in starting the new school, Saturn staff and parents worked with the school board to select a permanent site in downtown St. Paul. The former YWCA building was chosen, and renovation plans were developed late last winter. The staff worked closely with the architect to carefully design spaces that reflected the school's vision. Rooms were designed to fit various functions. A recent visitor remarked that there isn't a single room that looks like a traditional classroom. In fact we don't call any rooms classrooms. There is an art room, a science room, music room, writing labs, a study, some multi-purpose rooms, *Discourse*™ rooms, computer labs, and an enormous cooperative workroom, which includes our small media center. The building also includes a wonderful gym, pool, and combination auditorium/cafeteria that were existing features.

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As the building was essentially gutted and the interior rebuilt to our specifications, we were able to wire each room with video and computer networks. In each learning area, we designed "teaching stations" that include a monitor to display networked video or local VCR or videodisc input and a Macintosh on the "Teacher Network." Many rooms also include Macs on our "Student Network." Since the rooms are designed for specific activities, teachers do not work out of a particular room all day, but use the space that fits the needs of each course. Each teacher has a personal work area in the administrative area that includes a large staff work room, conference spaces, and lounge.

Saturn is a learner-centered environment. The curriculum is not content-driven, but process-oriented.

In January of 1991, Saturn moved into its new home. Located downtown, students have ready access to the larger community. Unique relationships enable Saturn students to take regular advantage of the resources available at the Science Museum of Minnesota, the St. Paul Public Library and the Minnesota Museum of Art.

Working closely with parents, Saturn staff have attempted to create an exciting and engaging learning environment that honors the gifts, needs and interests of each learner. Each student has a Personal Growth Plan (PGP) that includes academic, social, and wellness goals. The PGP is developed by the student in consultation with parents and advisor.

The staff compiles goals from the individual PGPs and uses the information to design courses that match the expressed needs and interests of the students. Students register for courses that include a core of reading, writing, and mathematics, and a wide variety of interdisciplinary offerings. All courses are open to students at all grade levels, so teachers face the challenge of creating learning opportunities for fourth through seventh graders.

Saturn is a learner-centered environment. The curriculum is not content-driven, but process-oriented. We do not use standard textbooks, except as resources. Many courses are project based. Students are encouraged to work cooperatively, though they may work independently, if they choose to. Emphasis has shifted from remembering the important facts presented by the teacher to finding, organizing, and making sense of the wealth of factual information available to today's student. Teachers enable learners to engage in a rich variety of experiences, and challenge them to make meaning for themselves. Knowledge is constructed through the personal experience of each student.

Although there is a good deal of technology available at Saturn, it is not a technology-driven school. It is a learner-centered school that provides students with access to technologies. There are five distinct ways that technology is used by Saturn students and teachers:

- tools for individualized learning
- tools for group interaction
- tools to manage and coordinate student learning
- tools for student expression
- tools for knowledge production

INDIVIDUALIZED LEARNING

A teacher rarely presents information to a large group of students. More frequently the focus is on individuals or small groups of students. Useful technologies include integrated learning systems (ILS) and stand-alone software and hardware.

Integrated learning systems (ILS) offer each student opportunities to develop reading and math skills, starting at a level that reflects their current performance, and progressing at his or her own pace. We use the ILS as a kind of insurance policy to insure that students who need to develop foundation skills get a daily opportunity to exercise these skills. The ILS does not replace the teacher; it enables the teacher to take on a different role, not as a presenter or manager of information, but as coach or guide to assist the learner. You may have trouble spotting the teacher in the ILS lab, as she or he is frequently kneeling next to a student, listening to them explain a difficult problem. The teacher helps students reflect on what they know, and sometimes seizes the teachable moment to do some direct teaching. The ILS provides feedback on student performance. The teacher helps students interpret the feedback, and makes adjustments when necessary.

We are currently using Jostens ESC and the CCC system and are engaged in researching the advantages and disadvantages of each. Some students prefer Jostens ESC system as it has elaborate lessons that present information in the context of interesting color graphics; many also include audio input. The system presents a spiraling series of lessons that follow a prescribed sequence. Students work through each lesson at their pace. Reports of student performance are generated by the system and provide the teacher and parents with information on student progress.

The CCC system has a more straightforward presentation of information, but is more responsive to the learner's performance. When students answer several questions correctly, they are moved along to the next level of difficulty by the program. If they answer several incorrectly, the program moves them to a less difficult lesson. The system not only tracks each student's performance, it adjusts lessons to fit the performance of the learner. Reports summarize student performance.

Some students have found that ILS offers them a safe way to work on skills they lack, without public embarrassment.

We are involved in the ongoing process of matching the tool to the needs of individual learners, as opposed [to] having all students engaged in the same experience. Some students are quite comfortable with ILS and are making steady progress. Others vary between being challenged and bored, based on the quality of the lesson or their past learning experience. Some students have found that ILS offers them a safe way to work on skills they lack, without public embarrassment. Children who have difficulty reliably associating meaning with symbols clearly benefit more from a hands-on approach than independent work at a computer. Students with strong skills may specify more independent or project-oriented approaches to skill development on their PGPs. At this time, all of our ILS work is individual, but as staff become more familiar with the software, we anticipate bringing groups of math, reading, science, or social studies courses to work on particular lessons that interact with and reinforce learning in courses.

Another tool for individualized learning is stand-alone drill and practice and simulation software. There are hundreds of stand-alone programs that present information in virtually every subject area. These programs can be very effective ways to extend and support learning. Teachers who know a good deal about available software, the curriculum, and the students they serve can make optimum use of this software. Through courses or independent study projects, students learn to use a variety of MECC, Sunburst, and other software available on our AppleIIcs LANPRO network. Math courses use the lab for practicing skills, geography classes travel the world on disk, and science classes simulate experiments.

Students working independently or cooperatively also have direct access to more open and flexible tools such as CD-ROM-based reference materials and encyclopedias, video and audio libraries, and online data-base and library resources. There is a great wealth of information available through these technologies, which students may access to "present" information to themselves. The PGP enables students to specify and record learning, which they engage in through use of these powerful tools.

Computers present a realistic means for developing and managing individual learning programs.

GROUP INTERACTION

The *Discourse System*™ is an innovation that connects individual students with the teacher's computer via "Studycoms," keyboards with small text windows. The teacher (or a student) presents information, and requests a response from each student through the Studycoms. The presenter can view all student responses simultaneously on his or her computer screen. The presenter may develop lessons on disk that will present text or control a videotape, videodisc player, or slide projector. Questions may be prepared in advance or be displayed on the monitor during a live lesson. Individual student responses may be displayed on the large monitor for class discussion, and may be stored on disk.

Once again, we are learning how to use this technology to meet the needs of learners and teachers. The *Discourse System* may be used as a didactic presentation and management tool, or can be used as a very open-ended brainstorming and discussion tool. One teacher uses *Discourse* in a math course, and can easily check and record all student responses. Another teacher uses the system to teach research skills. As students learn note-taking, they have a chance to see what classmates have chosen as key words and phrases. *Discourse* can also be a terrific vehicle for brainstorming with students or staff.

Manage and Coordinate Student Learning

Technology offers powerful tools for managing information. Beyond the storage and retrieval of student records and performance on tests, computers present a realistic means for developing and managing individual learning programs. We are developing software that will facilitate the process of setting goals and tracking student accomplishments. Instead of emphasizing course outcomes or the goals that teachers set, we are working on information management tools that help students become responsible for planning and accountable for keeping track of their own learning.

The software is flexible and allows users to capture key elements that emerge from the interpersonal growth planning process, without interfering with the process. Rather than check off outcomes from an arbitrary list (generated by the state, the district, or any selected group of experts), available computer technology makes it possible to keep track of meaningful outcomes that each learner actually achieves in accomplishing personal goals. The student's advisor has an active part in the process, helping students make choices and validate learning. Regular reflection on and recording of key learnings that take place, enables students and teachers to share authentic accountability for what each student actually learns.

Each student has a portfolio of proficiencies that includes examples of work from courses, writing samples, and special projects. In addition to papers and drawings, a student's portfolio may include photographs, video or audiotape segments, and data disks. Over time, this portfolio may become the student's "Career Book," a record of what, when, and how they have learned throughout their school experience. Life-long learning is a desired outcome of the schooling process. We are working to prepare learners to use technologies to set goals for themselves, access resources, and reflect on and map their growth and development over time.

STUDENT EXPRESSION

Students develop responsibility for learning, in part, through sharing what they learn. This use of technology differs from presentation of information, as it focuses on ways that learners can demonstrate, can re-present information in their own voice. Providing students with access to many modes of presentation helps each to find his or her own voice, their unique way to join the conversation of learning. For some, the world of words is comfortable; others prefer a more visual, auditory, or tactile approach. A learning environment that offers diverse tools can meet the needs of many learners.

All Saturn students take part in a whole-language approach to writing. Everyone writes every day. Last fall, one fifth grader in my class would draw sketches, accompanied by the briefest of comments.

He actively avoided writing with pencil and paper: "I need to sharpen my pencil," "I need to go to my locker to get my paper"—anything to get out of writing. When the class got access to Macintoshes, that all changed. I can still see the look on his face when he was so engrossed in his story that he asked if he had to leave when class was over. It is hard to believe how many students have become willing, even prolific writers when they have access to a Mac and a LaserWriter. Desktop publishing is a wonderful tool for combining text and graphics in a personal publication. Scanners and video images enable students to combine what they see with commentary, description, or analyses.

Video and multimedia productions are powerful ways to document and share learning. At this time, several students have learned to use video cameras and editing equipment and act as resources to the rest of the school community. We have recorded students displaying their art projects at the museum, demonstrating science projects, and acting in dramatic performances. Video is a wonderful way to capture the activities of tactile learners, and enables students to describe what they are learning as you watch them in action. A wide variety of student learning can be shared with audiences both within the school and in the larger community via the local cable-access channel.

Video and multimedia productions are powerful ways to document and share learning.

Telecommunication networks link learners around the globe. Direct sharing and extension of learning through engaging in dialogue with others (who may support or question a student's views) helps students develop their own voices. Learning is a dynamic, ever-changing process. Tools that enable students to share learning through interactive rather than static means help underscore the message that learning is never finished.

KNOWLEDGE PRODUCTION

Through technologies, students are able to create what had never before existed, at least in their experience. *LogoWriter*, *LEGO®TC logo*, *HyperCard*, and *HyperStudio* multimedia pieces, original video productions, graphic design, animation, and synthesized music are just a few of the tools that enable students to create. Given the opportunity to explore these "microworlds," children make personally significant discoveries. There is, in my experience, no more excitement in school than an exchange around "How did you do that?" "Here let me show you. I just did this, and then. . . ." Collaborative learning is at its peak when a new bit of information is discovered; kids literally line up to learn from each other.

While technologies act as a catalyst in school reform, they cannot direct change.

These tools enable students to create personal knowledge within several curriculum areas. In "HyperCard Geography" students learned *HyperCard* as a means to collect, integrate, and present what they learned about the state they chose. While all projects included components such as a map and descriptive text, there was enormous variation in complexity and design. Students were excited about ways to demonstrate the geography they were learning. *HyperCard* has also enabled students to do autobiographies that include scanned photos, video images, and audio segments.

LEGO®TC logo has presented students with opportunities to learn about principles of physics through personal experience. Levers, gears, and pulleys make sense when they are just the thing needed to get their machine to perform. Logo enables students to program their machines. Sensors feed information to the computer, enabling students to build in control mechanisms.

These technologies present students with possibilities for new learning, both about the world and about themselves. Students may learn "I am a creative person," or they may develop a sense of efficacy—"I can solve this problem." It is wonderful to have children ask a question, then tell you how much of an answer they want: "Don't give me another idea, just tell me what I have to do to get my idea to work."

Teachers have to be very careful to honor the learner in these situations. Many times an astute teacher can see an opportunity to show a student a better or more efficient way to proceed. I have found that students would rather not hear about my great idea in the context of their current project. It is often easier for them to hear my idea after the fact, when they have already found a personally satisfying solution. Sometimes the most useful role for the teacher is that of sounding board. Instead of trying to teach students how they should think about a problem, I try to help them understand how they do think about it.

Technologies are tools that can be used to achieve many different purposes. While technologies act as a catalyst in school reform, they cannot direct change. Change is driven by vision. Appropriate tools are selected to bring about the vision. Designers of school reform can use technologies to enhance new environments, to bring about new visions. I believe that is not sufficient to reform schools; we must transform them. It is simply not enough to do what we already do in traditional schools more efficiently or more economically. We must use new technologies to enable students to learn what they do not or cannot learn in traditional learning environments.

At Saturn we use technologies to create learning opportunities that meet the needs, abilities, and interests of each student. To achieve this, teachers must be prepared to embrace a wonderful variety of technologies as tools for individualized learning, group interaction, management of student learning, student expression, and knowledge production. Our teachers don't know everything there is to know about all of the technologies we have. They are willing to learn how to use these technologies with their students. They aren't afraid of making mistakes, because they recognize that we are all learners in this unique learning environment.

Section 2

Transforming Teaching with Technology

It's not easy for the teacher to find simple ways to include technology in the day-to-day lessons or planned curriculum required of them. Many software programs are interesting and may be effective in what teachers present, but it is not at all clear how to integrate them into everyday learning. Fortunately, new software (particularly CD-ROMs) and the Internet (including the World Wide Web) are easy to include in student research, referencing, and reporting. They are also ideal for group work when equipment is limited.

Authors Van Dusen and Worthen raise the basic question, "Can Integrated Instructional Technology Transform the Classroom?" It's one thing to use technology for different instructional settings, but quite another thing to truly transform classroom learning activities. Their article cites the result of several multi-year studies that looked at the use of ILS (Integrated Learning Systems) to provide intensive and individualized computer-based instruction to students, tutoring and testing them in their basic skills. The research is mixed in its results. Some studies found students made large gains, others found no such impact. My personal experience raises the same point as the authors: Whatever happens with the computer activities must be tied closely with other classroom activities. Otherwise, there is little lasting benefit. Just as important is the need for staff training to use these tools well.

In "Communication through Multimedia in an Elementary Classroom," Elizabeth Riddle writes about her research findings that suggest students need more than one form of media to enhance idea development and individual expression. The fourth grade students and teacher use a multimedia software called MicroWorlds, which combines the programming aspects of Logo, KidPix, and HyperCard. Each of these applications allows students to write their own programs to solve various problems or challenges. The multiple forms of media assist the students by adding richer descriptions, different perspectives, and a diversity of background, interests, and skills.

Riddle examined the students' attitudes and behaviors and compared their work in both single and multimedia formats. She found that multimedia improves cognitive development, meets the needs of diverse learning styles, and addresses multiple intelligences issues. Moreover, multimedia is highly motivational for students compared to other learning modalities. In addition, Riddle observed that the students in the study were never bored. They elicited more expansive responses in their work and focused their concerns on new ways to solve problems. There was peer collaboration and willingness to present work to others.

In "Virtual Reality and Multiple Intelligences," Hilary McLellan takes a close look at the connections between two relatively new concepts: virtual reality and multiple intelligences. She defines virtual reality as a "class of computer-controlled multisensory communication technologies . . . an environment created by the computer in which the user feels present." The more powerful the system, the greater the control the user has, simulating "realities" ever closer to actualities. The user has to think, "What if I did this or moved toward that? What if I touched this or created that?"

It is not hard for us educators to conjure up powerful learning settings whereby the learner re-creates classic discoveries and problem solving—dropping and noting the speed of various objects, writing the first draft of a Declaration of Independence, landing a space module on Mars, and so on. The dream's the limit. Virtual reality, according to McLellan, lets "teachers represent information in forms that are most compatible with a student's particular learning style, selecting interactivity options that match student performance characteristics. There can be simulated hands-on learning, group projects, discussions, field trips, and concept visualizations. There are many exciting applications that address unique approaches to learning, better meeting student's unique learning styles. There are many examples in this article that give the reader a vivid sense of the new possibilities in this "near-science-fiction" reality. It's an exciting time to be a learner . . . and a teacher.

Can Integrated Instructional Technology Transform the Classroom?

by Lani M. Van Dusen and Blaine R. Worthen

A recent two-year national study of an integrated learning system suggests that, when used appropriately, such systems have great potential for improving students' achievement. Unfortunately, in too many cases, the systems are not used as intended.

Of all the technological innovations aimed at transforming teaching, one of the more controversial is the computer-based integrated learning system (ILS). These systems include courseware and management software and run on networked hardware. They cover one or more curriculum areas across grade ranges, and usually include a management program that tracks and reports student progress (Wilson 1990). Proponents of such systems argue that they increase student motivation and enhance individualized instruction, thereby improving student learning.

After five years of studying the effectiveness of ILS, we have concluded that the systems do have enormous potential but are infrequently implemented fully. This conclusion is based on several studies we conducted for local school districts, as well as a two-year national study conducted for an ILS agency. (In the latter study, we were employed by an independent research firm. Additional external researchers critiqued and verified the validity of the study design, instruments, analysis and interpretation.)

THE KINDS OF INSTRUCTION POSSIBLE

Most ILSs include instruction and practice problems in basic school subjects such as math and language arts, although some also include

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computer skills, science, writing, social studies, foreign languages, and even entire English-as-a-second-language (ESL) programs. Several systems provide for the entire K–12 curriculum. The instructional design of most systems follows behaviorally oriented programmed instruction. Each lesson is tailored for the specific learning level of the student and builds in a sequential fashion in the same manner as a basal textbook.

Recently, some ILSs have moved beyond this simple drill and practice by adding materials that require students to delve into complex problems in ways that promote deep reflection and genuine understanding (Becker and Hativa 1994). For example, some systems include science simulations that teach the scientific method by illustrating the beginning of an experiment and requiring students to hypothesize about outcomes before completing the simulation. Some language arts lessons encourage discovery learning by allowing students to explore topics through a branching program before defining specific vocabulary or presenting the overall theme.

Such ILSs follow more of a constructivist view of learning by providing a rich learning environment. Word processing programs, spreadsheets, mathematical graphing programs, encyclopedias, and thesauruses are only a few examples of the software and other resources that allow students to construct meaning and enhance critical thinking.

THE ASSESSMENT CAPABILITIES

One essential feature of all ILS management systems is their ability to track student progress on learning activities from the point at which students log on the computer to the point at which they log off. When the student begins a lesson the next day, the ILS automatically adds to the assessment file for that student. The most basic function of these files is to provide feedback and to record each student's response to traditional class-type tests. In addition, many systems can also evaluate student learning with alternative forms of assessment. Holistic computer scoring of student writing samples and computer management of student portfolios are examples of assessment approaches that are currently being refined for use with an ILS.

THE PHYSICAL CONFIGURATION

The ILS software is used on a central file server computer that is networked with as many as 30 or 40 student computers. From the system's central server, specific lessons are automatically sent to each student's computer when the student logs on. The lesson selection is based on the ILS's cumulative assessment of the student's prior performance and current learning needs in that particular curriculum strand.

Proponents of these systems argue that they improve student learning.

Most systems are designed to be used in either a computer lab or a distributed configuration. In a lab, 20–40 student workstations are contained in one area, along with the file server to which they are networked. Teachers may bring their entire class to the lab, where they—or trained lab attendants—use the ILS file server to deliver the tailored instruction to each student and then monitor to ensure progress. Labs may also be used by a teacher to deliver whole-class instruction by calling up the same lesson on all computer stations.

In the distributed configuration, a few computers are typically located in each classroom and are networked to the centrally located file server. Only a few students work on the computers at any one time, while the remaining students are engaged in other activities. Although teachers can use the in-class computers to deliver the same lesson simultaneously to a small group of students, students in distributed configurations usually move at their own pace within their individually prescribed curriculum.

WHAT DO WE KNOW ABOUT ILS EFFECTIVENESS?

Proponents of these systems argue that they improve student learning. Whether or not one views research as supporting this claim depends in large part on the type of evidence one chooses to trust. For some educators, testimonials of informed users—students, teachers, curriculum specialists, and administrators—carry great weight. Thus, questionnaires and interviews that convey the sentiments of such groups are accepted as important evidence. Experts' observations of the system in use are, to some, far more trustworthy than typical quantitative data such as students' test scores. They prefer case studies rather than classic, experimental control group studies.

Other educators view case studies and anecdotal evidence as quaint and provocative, but not scientifically defensible. Opinions may be interesting to such persons, but they carry little weight when compared to quantitative evidence collected by tests or more direct measures of student performance. Little short of carefully controlled experimental or quasi-experimental research is accepted by such educators as evidence that any instructional system or approach is effective.

ILS researchers have used both approaches. Numerous studies have shown positive student, teacher, and administrator satisfaction with the systems (Sherry 1990, Trotter 1990). However, many of these studies did not address the impact of the ILS on student achievement. Of the studies that did examine student learning outcomes, many reported large gains on standardized test scores (Trotter 1990). However, Becker (1992a) has noted methodological flaws in many of these studies and, in a meta-analysis of nearly 100 of them, concluded that they provide little conclusive evidence of ILS impact on achievement. Where differences were found between the achievement of ILS users and comparable non-users, Becker concluded they were too small to have any educational significance.

Once again we seem to be left with the limp conclusion that "research results are mixed." For those who are comfortable with casually conducted comparative studies or who accept testimonials of practitioners and opinions of expert observers, the effectiveness of the ILS has been amply demonstrated. The jury is still out for those who demand the rigor of decisive experimental evidence.

THE UNDERUTILIZATION OF ILSs

Our research (Van Dusen and Worthen 1994) has led to yet another conclusion: We believe that the reason prior research results are equivocal may be that they have underestimated the impact of these systems. This would explain the apparent contradiction between testimonials of ILS users and the results of rigorous experimentation.

Why have most scientifically rigorous studies of integrated learning systems failed to demonstrate their impact? We believe that the "no impact" findings may reflect a failure of such studies to examine one very critical question: Has the ILS been implemented correctly and in the manner its designers proposed as necessary for its effectiveness?

This underutilization of such systems—the failure to use them in accordance with specific guidelines and practices designed to achieve optimal performance—has been documented (Sherry 1990), and it became apparent to us during the first year of our national study. In none of the sites participating in our study was the ILS being used to its full potential. In some schools, students were spending as little as 10 minutes per week on the system! Given such astonishing underutilization, we were not surprised to find that students in the ILS schools showed no greater gains in achievement or attitudes than students in non-ILS schools.

We believe that underutilization is a fairly pervasive and serious problem, one that undermines the effectiveness of the ILS.

During the second year of our study, the schools were encouraged to improve their implementation. As a result, students spent significantly more time on the ILS, and teachers were much more involved in integrating the system with classroom activities. The results were startling: Students participating in the ILS classes scored higher on standardized tests than did those in traditional classes. The effect size for full implementation in reading was +.44, nearly a half standard deviation gain. Similar results were found when using objective referenced tests. Performance in reading and math were both statistically and educationally significant, with large effect sizes of +.40 and +.52, respectively. In general, as the level of implementation and teacher integration increased, so did student performance and student and teacher effort.

We believe that underutilization is a fairly pervasive and serious problem, one that undermines the effectiveness of the ILS. No system can be expected to realize its full potential until and unless it is fully and properly implemented. Using an underimplemented ILS will have as little effect on transforming the classroom as taking a fraction of a prescribed drug dosage will have on curing an ailing patient.

HOW CAN AN ILS TRANSFORM THE CLASSROOM?

The findings of our study show that an ILS—if used appropriately—has real potential for improving student achievement. This conclusion is further supported by studies we conducted for several school districts. (Each of these studies has been funded by the school district, not the ILS vendor.) We have held focus group interviews with more than 100 teachers and principals, made more than 100 structured classroom observations to chronicle ILS use and integration with classroom curriculums, received surveys from nearly 300 ILS teachers and administrators, and obtained achievement and attitude data from nearly 5,000 students. While there is variability in all of these data, the following conclusion seems warranted: If implemented properly, ILSs do produce positive results. Indeed, they have the potential to transform the classroom into a better environment for learning.

Such positive transformations, however, are often accompanied by challenges. The five areas in which classroom changes can occur are described below.

Increased Time-on-Task

In ILS classrooms, students are motivated to learn. They enjoy working on computers, and they like the animated characters, voice capabilities, and full-color graphics. Because they can progress at their own pace, and because they receive immediate feedback, students remain engaged. This is important because increased time-on-task has been shown to improve student performance (Doyle 1983). We found that time-on-task increases significantly with use of the ILS (Worthen et al. 1994). The average engaged time for ILS students was 87 percent, an increase of nearly 20 percent over the traditional classroom.

Computerized Learning Resources

Integrated learning systems can facilitate research and exploration within the classroom. Because these systems include extensive tool and database software (for example, word processors, reference programs, spelling and grammar checkers), students can explore new content, solve problems, and create new concepts and associations.

Writing assignments are included in many ILS language arts programs. These programs usually include feedback loops that are based on student responses. Thus, the ILS has the potential for reducing the number of teacher-scored assignments. Many ILS management systems also accommodate third-party software that will assess writing and store writing samples in a printable form for portfolio management.

Effective Assessment and Reporting

These systems have the potential to provide user-friendly assessment reports. Their management systems can generate assessment files that contain a wealth of information. This includes such routine information as the correct percentage of responses for each exercise attempted, as well as less traditional information, such as the specific learning objectives covered, the amount of time required for a student to attain each objective, and the number of remediation cycles required by that student. This kind of information is vital if a teacher is to adequately plan appropriate learning activities for each student, yet it is nearly impossible to chart in the traditional classroom. In addition, most ILSs allow teachers to customize reports to meet their specific needs.

Unfortunately, our research revealed that most teachers (over 80 percent) do not, at least initially, use ILS reports. Many teachers find it daunting to work with the computer to obtain the printouts, and many have difficulty interpreting the vast amount of information contained within the report. Inservice training would help to ensure that teachers can take full advantage of these reports.

Integrated learning systems also have the potential for accommodating alternative assessment, such as portfolio management and scoring of student writing. They can facilitate such product, process, and performance assessments as learning logs, student journals, "think aloud" process descriptions, and self-assessment checklists. However, because the teacher must find the third-party software and the administrator must secure funds to purchase it (adding to the ILS's already considerable price tag), few schools have such supplements.

Guaranteed Individualized Instruction

The ILS allows the teacher to individualize instruction to fit each student's needs. Because the system organizes content into small units, based on the learner's ability, each student can make progress. Students who learn quickly move through the curriculum at a rapid pace. Those who need additional time and extra exposure receive it.

Such individualized instruction can eliminate the need for age-based grade levels. Elementary school students can simultaneously function at several different grade levels within different subjects. Students in secondary schools can be released from the strictures of particular grade-level curriculums and work toward mastery of particular curriculum strands and themes. And, ILSs are increasingly popular for use with ESL students. Several vendors offer ESL programs that allow students to continue using their native language, while being mainstreamed at a level they can handle.

Several vendors offer ESL programs that allow students to continue using their native language, while being mainstreamed at a level they can handle.

Learning theory suggests that an individualized program that caters to specific learning needs will lead to greater student gains, while also decreasing the gap between low- and high-ability students. There is evidence, however, that excessive individualization may actually detract from average-ability student performance (Becker 1992b). Thus, when the ILS becomes the only source for learning, some students may suffer from the lack of teacher interaction.

This problem can be overcome by using the ILS in conjunction with other learning activities. For example, one fifth grade teacher (Blickham 1992) relates that while some students work on the computers, she assigns seatwork to others, allowing her to spend time with small groups of students with similar needs. The ILS also allows the teacher to conduct one-on-one tutorials with students. This change, however, requires a fundamentally different role for the teacher.

New Roles for Teachers

The most obvious difference to the observer of an ILS classroom is the role and behavior of the teacher. In traditional classrooms, teachers are the focus of most activities. Most of their time is spent in direct instruction. The balance of their time is spent performing burdensome clerical tasks, including assessment and reporting activities.

The role of the teacher changes dramatically in the well-managed ILS classroom. Teachers are still responsible for students' learning, but rather than being dispensers of information they become guides to the learning process. They act as facilitators and organizers of learning activities; they are free to focus on small groups and individuals who need more specialized attention; and they can coach their students in how to process information, helping them to make choices and validate their learning.

The importance of this new role for the teacher cannot be overemphasized. Our studies have shown that the extent to which the teacher integrates the ILS and classroom content is the most important factor in producing student learning gains. Unfortunately, most teachers see the ILS as a supplement to, rather than an integral part of, the classroom. This is, perhaps, the greatest challenge schools face in incorporating the ILS into the classroom.

The main reason educators flounder in their efforts to initiate change is that they lack a strategic plan for how those changes are to occur.

ESSENTIAL INGREDIENTS IN USING THE ILS

If an integrated learning system is to be effective, it must be implemented correctly. Researchers have collectively identified six key criteria that are present in schools where an ILS has been effective in improving student achievement.

A Sound Implementation Guide

The main reason educators flounder in their efforts to initiate change is that they lack a strategic plan for how those changes are to occur. An implementation guide that clearly identifies the objectives for using the ILS and assigns specific roles and responsibilities that must be accomplished to meet these objectives is critical to its successful adoption. Vendors typically supply this guide, but schools may wish to refine or extend it as needed. At a minimum, the implementation guide should address each of the remaining criteria.

An Appropriate Hardware Configuration

One of the first decisions that a school must make is whether to set the ILS up in a lab or in a distributed configuration. While both configurations can be successful in providing students with individualized learning and assessment, if classroom instruction is to be transformed and maximum teacher involvement and integrating with other class activities is to be ensured, students must have easy access to the computers (Robinson 1992). Some schools we have observed have made good use of a combination of approaches: Each class has several computers in additional to a centralized lab. In this way, small groups can work on the classroom computers and periodically the entire class can work together in the lab.

Adequate Time on the ILS

In a well-run ILS class, the software becomes the primary information provider. Therefore, it is essential that students spend a substantial portion of their day working on the computers. Our studies suggest that each student must spend a minimum of 30 minutes per subject area per day on the computers to achieve significant learning gains.

Ironically, it is a commitment to an egalitarian ethic that often ensures that students do not meet this minimum. When they are unable to purchase enough computers to give each student a full complement of time, educators typically shorten every student's time, thus reducing the system's effectiveness for everyone. The notion of selecting some students to receive computer instruction while others receive none is simply not palatable in most schools.

Among the factors that influence the integration of the ILS and classroom activities, one of the most important is bridging among various learning activities.

Adequate Computer Equipment

It is essential that enough computers are available for each student to have sufficient time on the ILS. For example, if the ILS is to be taken in four basic subject areas, each student should average 120 minutes per day on the system (30 minutes in each area). Given that there are typically 360 instructional minutes in a day, at a minimum the school would need one computer for every three students.

Effective ILS Teaching

The biggest obstacle to effective use of an ILS is the challenge teachers encounter in integrating it into the classroom. Just as its name suggests, an ILS requires integration with other classroom learning activities. An ILS curriculum is not intended to supplement the class curriculum; rather, there should be one curriculum that is presented through a combination of ILS activities, small-group instruction, one-on-one tutorials, and other activities. This means the teacher must learn how to select and schedule the most valuable learning events at the most appropriate times.

Among the factors that influence the integration of the ILS and classroom activities, one of the most important is bridging among various learning activities. For example, a teacher might assign a small cooperative group to conduct a hands-on science experiment. This activity should involve the same concepts the students are being exposed to on the ILS. The coordination among ILS instruction and other classroom activities will require the teacher to become as familiar with the ILS curriculum as he or she is with the textbook. Clearly, this is not a trivial undertaking and it may initially increase the teacher's workload.

Supportive, Visionary Administrator

Administrative support is a key to the success of ILS instruction. First, administrators must provide leadership in the decision to adopt an ILS. Once the decision to adopt an ILS has been made, they must support teachers in their shift from information dispenser to integrator of learning activities. Part of this support should come in the form of inservice training. Sherry (1990) suggests one to two full weeks as a minimum. Unfortunately, however, his research reveals that fewer than 10 percent of teachers in schools adopting an ILS have even five days of training in its use. Administrators should also encourage teachers to experiment with new uses of the ILS.

IN SUMMARY . . .

One might wonder if any fully implemented ILS classrooms exist. The answer is yes, but they are not yet abundant. Such an effort requires a major commitment of resources and professional energies, as well as an ample measure of patience. Research (Cook 1994) suggests that it will take a minimum of three years for most schools to establish a fully functioning ILS.

Our studies show that if adequate time and effort are invested, an ILS has the potential to restructure the classroom and transform teaching in ways that will result in improved student learning. But this potential can only be realized if schools are committed to adopting—*and implementing fully*—a well-designed system.

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Communication through Multimedia in an Elementary Classroom

by Elizabeth M. Riddle

The emergence of multimedia software in the classroom challenges the traditional use of single media as the medium for student communication. Educators need to know how to use this new technology as an effective tool in their students' learning. The purpose of this study was to observe how students express themselves differently using MicroWorlds, a multimedia software. The findings suggest that students use multimedia tools to enhance idea development and individual expression by adding greater description, unique perspectives, and revealing diversity in their backgrounds, interests, and skills. In a single media format such description, insight, and individuality is difficult for students to convey.

THE PROBLEM

Need for Study

One of the most powerful and inescapable influences in our society is the domineering force of the media. Media bombards people in the form of television, radio, videos, magazines, billboards, and newspapers. Through media, ideas are expressed, opinions formed, lifestyles verified, and decisions condemned. The growth of mass media has drastically changed the dynamics of the world. Society has become accustomed to the steady flow of information. Media, properly used in the classroom, can provide incredible opportunities for students and teachers to obtain information as well as express themselves.

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In a changing world, it seems irresponsible of educators to remain loyal to traditional and conventional strategies because they are familiar. The presence of computers in classrooms can be viewed as revolutionary in terms of comparing them to classrooms without them. However, the infusion of computers in schools needs to be viewed as an evolution in the classroom rather than a revolution. It must be viewed as an on-going process rather than a one time event (Dyrli and Kinneman, 1994). Through the use of computers, educators can effectively utilize the widespread influence of media in the classroom as a source of education rather than just entertainment.

In a changing world, it seems irresponsible of educators to remain loyal to traditional and conventional strategies because they are familiar.

Computer software that combines multiple types of media is considered multimedia software. Multimedia refers to the integration of text, graphics, animation, sound, video, and music, all under the computer's control (Turner, 1992). Multimedia software is a relatively new concept in software. It demands active participation and provides the opportunity for users to manipulate and express themselves through graphics, animation, sound, video, and music. Because students of all ages are so familiar with media, multimedia software may be able to inspire motivation and access creative thoughts that paper and pencil can not.

Teachers need to be educated about the use of multimedia in the classroom as a learning tool. They must be prepared to make educated decisions about the learning tools that new techniques provide. In order to access student knowledge, teachers and students need to be exposed to a variety of strategies. Multimedia software equips teachers and students with aural, visual, and textual strategies for communicating knowledge. Therefore, multimedia software merits more attention in the classroom.

Purpose of Study

The purpose of this study is to observe how a fourth grade class manipulates a multimedia software to express themselves differently than they do with the traditional paper and pencil process. By introducing multimedia software, MicroWorlds, students will be able to express themselves in a much more elaborate way. Through comparing student attitudes, behaviors, and quality of work, I plan to reveal some significant reasons why teachers should use multimedia software as an advantageous medium for student communication.

Hypothesis
Students' writing will be enhanced through use of MicroWorlds, a multimedia software program. Use of this software in this way will enhance idea development and facilitate individual expression. Through the review of literature, implementation of multimedia software in a classroom, observation of attitudes and behaviors, and comparison of multimedia and single media work, I plan to offer insight into the value of using multimedia software as a tool for teaching.

REVIEW OF LITERATURE

> "Now, five hundred years after Gutenberg, fifty years into the television age, and forty years after the introduction of the computer, we finally have—in one tool—the intellectual content of print, the images of video, the sensory impact of sound, and the speed of electronics."—David Z. Shefrin, President of Interactive Video Industry Association (Scarbeau, 1993, p. 4)

This "one tool" that David Z. Shefrin describes is called multimedia. Each individual invention that comprises multimedia has had an everlasting impact on the world. Now with the powerful influence of each invention, multimedia will change the dynamics of the world in which we live, especially in education. The multisensory experience that multimedia offers allows education to be an adventure that necessitates student participation. The advent of multimedia software has provided new avenues for student expression and communication beyond what has ever been possible when using single media formats.

Multimedia software integrates text, graphics, animation, sound, and video. It offers a medium to collect, store, manipulate images, sounds, and text on a computer as part of the knowledge acquisition process (Daiute and Morse, 1994; Gray, 1991). Furthermore, multimedia software solicits active participation from its user. Users browse, explore, make notes, add new information, create new things, and choose what to see and hear. The interactive and multisensory qualities of multimedia software enable students to express themselves and their worlds differently than they do with traditional learning materials. Expression and communication is facilitated visually or aurally with multimedia software, often giving students "real" experiences (Trotter, 1993; Turner, 1992). Multimedia software facilitates these natural learning strategies of seeing, hearing, and doing, through its variety of tools which provide rich information: pictures, written text, sound, animation, and video (Gates, 1993). Furthermore, children, accustomed to watching television, listening to music, and playing computer games, perceive a multimedia medium more compelling and motivating than the conventional "chalk and talk" (Turner, 1992).

Meeting Diverse Learning Needs

Multimedia software advocates new strategies for students to use in the process of learning. Traditionally teachers have relied on written communication to evaluate student learning. According to John Bransford of the Learning Technology Center at Peabody College of Vanderbilt, "[with multimedia] we may have the opportunity to break [this] mold" (Behrmann, 1991, p. 1). Multimedia breaks this mold by infusing a variety of strategies used for communication and expression that reach beyond the written confines of text. These strategies support a diverse range of learning styles that text alone cannot.

Multimedia software advocates new strategies for students to use in the process of learning.

Diverse learning styles need to be carefully considered when educating students. According to Brenda Litchfield (1993), learning styles can be defined as "various methods individuals have for perceiving and processing information while reacting to their environment" (p. 3). Teachers are challenged to meet the needs of their students' diverse learning styles and multimedia software is an invaluable tool in accomplishing this great task. Multimedia offers successful strategies for students having difficulties reading and writing to communicate (Turner, 1992; Wilson, 1992). An important factor in becoming an effective reader and writer, is the ability to use background knowledge of facts, conceptual frameworks, and goals (Daiute and Morse, 1994). The use of text can isolate students who are weak readers and writers. Use of text alone inhibits these students from utilizing the background knowledge they have received from nontextual sources such as real-life experiences, speech, television, and art. With multimedia software these nontextual sources can be accessed by students and used to express themselves. This expression for students with language processing difficulties is communicated through the manipulation of graphics, animation, sound, and video (Daiute and Morse, 1994; Prickett, 1992).

Published texts often do not represent the symbols of minority and peer culture that are easily accessible with multimedia software.

Although the development of reading and writing greatly relies on cognitive and linguistic factors, cultural and social factors can have great impact on language processing. The nontextual tools of multimedia enable students to incorporate their own cultural, social, or personal relevance in their work. This integration of individual expression empowers and motivates students beyond the confines of written words. When students have the opportunity to write about their own experiences, written production, elaboration of ideas and attempts to express personal and varied points of view are all likely to increase. Graphics, animation, sound, and video help facilitate the expression of emotion, increase memories of past experiences, and elicits more description of social arrangements and peer or family culture. These types of experiences are often difficult to convey with text alone (Daiute and Morse, 1994). Published texts often do not represent the symbols of minority and peer culture that are easily accessible with multimedia software. When students create their own relevant symbols, they are diversifying themselves by background, interest, and/or skill (Daiute and Morse, p. 252).

The nontextual tools of expression in multimedia software can also serve as a reference point, a catalyst, or a context for integration and reflection. They provide sources of information for thinking, processing, and reflecting on what they see and hear (Daiute and Morse, 1994). Varied learning styles are not isolated by multimedia. Therefore, by using multimedia, students can access and express their knowledge which will help teachers assess their students' knowledge more accurately.

Improving Cognitive Development

Along with supporting a diverse range of learning styles, multimedia tools can help improve cognitive processing. According to John

Sculley (1993), "Intellectual development is an active, inquiring dialogue with the world, a personal journey of curiosity and discovery" (p. 38). The opportunity to manipulate images, sounds, and text by cutting, pasting, cropping, drawing, altering, reconstructing, and examining supports this intellectual development. The active and prolonged engagement that multimedia software necessitates is essential for long term learning. Long term memory is enhanced with multisensory materials of multimedia. In Brian Scarbeau's research (1993), he states that "learners can retain about twenty percent of what they hear and see, and about seventy-five percent of what they hear and do" (p. 4). Schools that rely on multisensory experiences for learning are the schools where the most learning occurs (Gates, 1993).

The impact multimedia software can have in education alone is phenomenal.

Furthermore, when students can organize content in a meaningful structure as is possible with multimedia software, knowledge becomes more accessible to them. However, this organizational process provides a cognitive challenge to the student while maintaining an appropriate level of information (Turner, 1992; Wilson, 1992).

Motivating Students

One of the greatest attributes of multimedia software, beyond offering a variety of communication tools, is its motivational element for students. Although students seem to be inherently motivated by computers, the tremendous connection that multimedia software creates between student's academic world and social world is a factor in their motivation (Litchfield, 1993). Children who enjoy television, music, and computer games find multimedia software more enthralling and motivating than traditional medias. Multimedia software provides a sense of excitement in the classroom because it presents learning as an exciting adventure instead of a dreaded chore (Gates, 1991; Prickett, 1992; Turner, 1992).

It is concluded from information gained in the literature review that multimedia addresses a variety of learning styles, helps improve cognitive processing, and motivates students in their education. The impact multimedia software can have in education alone is phenomenal. Offering students opportunities to succeed is the obligation of educators. Multimedia provides students with new opportunities for communication that are not possible with traditional, single media formats. If the Chinese Proverb, "I hear, and I forget. I see, and I remember. I do, and I understand" holds truth, multimedia software may be the tool that leads to success for many students.

DESIGN OF THE STUDY

Sample

Eighteen fourth grade students at a public school in Charlottesville, Virginia, participated in this study. The group consisted of nine boys, nine girls, and nine of them minorities. The students had computer lab once a week for an hour. They had experience publishing with word processing software. Students did not have individual disks to save work on. Therefore all computer projects did not exceed one lab session. All students were familiar with ClarisWorks Word Processing and KidPix. Only three students were familiar with MicroWorlds, the multimedia software used in this study.

Measures

I used two students to collect insight on students' idea development and individual expression in writing their autobiographies in the different mediums. The questions focused on how much time was spent writing, perceptions of the assignments, and the peer collaboration that occurred. The first survey, "With Single Media" (Appendix A), asked students

- how much time did you spend writing your autobiography?
- what did you find the hardest thing about the assignment?
- how many drafts did you write?
- did you ask your peers for help? what kind?
- are you proud of your work? why?

Students answered the second survey, "With Multimedia," [Appendix B] after they finished their autobiographies with MicroWorlds. The answers were designed to be comparable to those of "With Single Media." This survey asked students,

- how did you change your autobiography with MicroWorlds?
- how did you like this writing assignment using MicroWorlds?
- did you ask your classmates for help? what kind?
- would you have liked more time to work on your project?
- are you proud of your work?

I also compared students' written work to their finished project, in terms of added revision and the number of multimedia tools used. The purpose was to gather comparison data on students' idea development and individual expression in the two medias. A daily journal was also kept on the events that took place in the classroom each day of the project. I recorded student behaviors and attitudes on the occasion of each visit. The content of journals and surveys were analyzed according to themes revealed in my research.

Design

In the first phase of this study students were engaged in a newsletter activity designed to acquaint them with the process of manipulating text and graphics when publishing. Students designed a layout for their newsletter to include articles on what they were learning in each subject, poetry by classmates, and two class pictures. After students wrote their articles they changed fonts and text styles to fit within the layout. This activity gave students experience with the tools for manipulating text and graphics that they would use in their MicroWorlds project.

The benefit of implementing learner-centered software, like MicroWorlds, is that students have the ability to develop materials that are meaningful and useful to them.

I chose MicroWorlds as the multimedia software to use in this study because of its learner-centered characteristics. There are three types of multimedia software: software that publishers develop for schools, software that teachers develop for other teachers, and software that students develop for themselves, which defines MicroWorlds. The benefit of implementing learner-centered software, like MicroWorlds, is that students have the ability to develop materials that are meaningful and useful to them. With this software students become empowered to communicate their ideas according to their individual needs.

MicroWorlds combines programming aspects of three different applications: Logo, KidPix, and HyperCard. The use of the turtle in MicroWorlds depends on the programming language of Logo. Students manipulate this programming language to create valid and pertinent materials. The KidPix aspect of MicroWorlds offer students a large variety of paint and draw tools, including numerous icons that they can utilize in expressing themselves. Finally, MicroWorlds' hypermedia dimension allows students to organize their ideas through linking them together in a structure that they find meaningful.

Students wrote their autobiographies in their regular classroom in four steps: birth, early years, school years, and future years. The students' teacher modeled the assignment by writing her own autobiography, reading it aloud, and giving each student a copy. Students were given five thirty-minute class periods to write their autobiographies. Due to time constraints and scheduling conflicts with the computer lab, students' autobiographies were typed into ClarisWorks documents for them.

Students were divided into two groups of nine to work in the computer lab. Twice a week students worked on their MicroWorlds project for thirty minute time periods for a total of ten periods. Students were introduced to MicroWorlds by learning how to "teach the turtle." By using the turtle's vocabulary, students manipulated the turtle by giving it commands to travel across the screen, create designs, and link to other pages. Students learned how to make text boxes and use the paint and draw tools of MicroWorlds while creating their own title pages for their projects. They created pages for their autobiographies, cut text from ClarisWorks documents and pasted them into MicroWorlds pages, and manipulated the size and font of text to fit in the desired text boxes. The procedures to use the multimedia tools: graphics, animation, and sound were taught to the students as options to enhance the already existing text or express new ideas. Because students were unfamiliar with these tools, a great deal of time was spent teaching the procedures.

Over the course of six weeks, students explored the multimedia tools of MicroWorlds and chose which ones to incorporate into their projects. This experience introduced them to multimedia software and a variety of possibilities for communication.

RESULTS

Two surveys were distributed to the students in order to collect insight on students' idea development and individual expression in writing their autobiographies in the different mediums. One survey was distributed at the beginning of this study. The first survey, entitled "With Single Media," was completed by sixteen of the eighteen students. The second survey, entitled "With Multimedia" was given to students at the completion of their projects. It was completed by fifteen of the eighteen students.

Students were given a limited amount of time to work on their projects, and within these time constraints, all of them enhanced their original text with multimedia tools. Only five students said they wrote more than one draft of their autobiography. All eighteen students used graphics, seven used animation, and eleven used sound to express ideas. The use of these tools expanded their ideas by allowing them to communicate through different methods than text alone. For example, Josh, a minority student brought a picture of his sister to scan into his "early years" page. Because she is a different race, this visual representation provided more description than Josh ever could have expressed in written words.

Many students, using multimedia tools, developed new ideas along with enhancing old ones.

Six students, on the "With Multimedia" survey, answered that they changed their autobiographies in MicroWorlds by "add[ing] description" or "mak[ing] it longer." Nine students responded that they changed it by adding pictures, sound, and/or animation to their autobiographies. With these changes, many students shifted from general, non-descript ideas to more specific, detailed, unique expression of these same ideas. Jeremyiah's text said that in the future he wanted to create things that mankind has never known. He developed this general idea further with graphics, revealing that he wanted to have a science lab in the desert. Although many students created graphics to represent hospitals and schools, they also chose different graphics that demonstrated different perspectives not easily detected from reading text alone.

Many students, using multimedia tools, developed new ideas along with enhancing old ones. Five students added new ideas through the revision of text, five through graphics, and one student used both. A common theme in many of the autobiographies emulated the following structure: "In first grade my teacher was . . . In second grade my teacher was . . . In third grade my teacher was . . . In fourth grade my teacher was . . ." As students worked on their projects, more description evolved. For example, in my journal I recorded, "Elaine's original text was very nondescript about her school years. She is now, however, adding new text about her dog. It is not just a 'dog.' It is a brown dog and she is determined to make her graphics realistic."

On the "With Single media" survey, eleven students stated that the hardest part of the assignment was thinking of ideas. However, with MicroWorlds students asked me questions on "how to do something" rather than "what to do." In a journal I reflected on how students approach to this assignment was changing. "I realized today that the only questions students ask me are on how to do a procedure. They ask for the mechanics not the ideas. No one has said to me 'what should I do?'"

Apathy or reluctance was never demonstrated in the computer lab. "'What are we going to do today?' was the first thing that was said to me when I walked in their classroom." Three students on "With Multimedia" said that they liked their MicroWorlds project because it was fun and Sara exclaimed how much fun the project was in her voice recording. The only reluctance that I ever experienced was at the end of our computer sessions. "Jeremyiah is known to be a discipline problem due to his abundant energy, which is apparent in our short walks from the classroom to the lab. The only time I have any difficulty with him is at the end of class. Getting him off the computer is like a game of tug of war."

When asked if they liked using MicroWorlds, all students said yes. Eight students like MicroWorlds because they could "do more things," two said they liked working on computers, three said it was fun, and one student said he liked it because "[he could] be more smartly."

Learning to "do more things" on the computer brought a sense of excitement to the lab everyday. When MicroWorlds was introduced by learning how to teach the turtle "the excitement level was extremely high. Everyone liked being the 'brain' of the turtle and experimenting with their power." Josh, overwhelmed with the prospect of scanning, proclaimed for a whole session, "That's just so cool!"

On the "With Single Media" survey, two students said they asked peers for help in spelling and on the "With Multimedia" survey, four students said they asked peers for help in spelling and procedures. In contrast to the surveyed answers, I observed a tremendous amount of student collaboration. During in-class writing, students worked independently, but in lab they continuously relied on each other's knowledge. In my journal I noted, "A lot of students are helping each other with the animation since the procedures have to be so precise. It helps me to have them answer each other's questions." MicroWorlds is so multifaceted that many students learned procedures through exploration. One day Malcolm told me that Sydney was going to help him since I did not [know] how to do what he wanted. At times this collaboration became a management issue as I stated in one observation, "It's great to see the kids helping each other but it is hard to have them getting out of their seats. They're dying to share their work and help each other but it's too chaotic to have them walking around!"

MicroWorlds is so multifaceted that many students learned procedures through exploration.

Students wanted to spend more time on their autobiographies in MicroWorlds than they did on paper. Eight students used the daily thirty minutes given for writing and two used more. However, all students answered on the "With Multimedia" survey that they would have liked more time to work on their project. This range of extra time spanned from wanting thirty more minutes to eighteen more years. In my journal, I observed, "One of my biggest complaints is when I ask students to save and close their projects. Almost everyday I have heard, 'but I'm in the middle of something' or 'Can't I have just a few more minutes!' It's hard for some of them to find a good stopping point. Someone always has 'just one more thing.'"

On both surveys all students said that they were proud of their work and the majority credited this pride to the fact that they worked hard. There was great anticipation for the day students shared their projects with the class. Twelve students volunteered to present their autobiographies in an "Author's Chair" activity.

In summary, all eighteen students enhanced the development of their ideas through the multimedia tools: graphics, animation, and/or sound. Many students developed new ideas using these tools. Students relied on the instructor for mechanical instructions rather than thoughtful ideas. Students showed high levels of motivation for their multimedia projects. More active peer collaboration occurred in the lab than in the classroom. Students not only utilized all of their computer lab time but said they would have liked additional time as well. And finally, all students were proud of their work in single and multimedia for the same reasons: hard work.

CONCLUSION

Using multimedia tools, students enhanced their autobiographies in MicroWorlds. Throughout the integration graphics, animation, and sound with text, several themes reoccurred.

Each project revealed the diverse backgrounds, interests and skills of each student.

Students tended to use graphics more than animation and sound to enhance and develop new ideas. While all students used graphics to enhance ideas, only seven students used animation and eleven students used sound. The disproportionate use of these tools can be attributed to students' previous experience with paint and draw applications and the novelty of using animation and sound tools. The integration of animation and sound in projects require precise procedures. The precision frustrated many students, which ultimately deterred some of them from incorporating more animation and sound in their work.

Although the complexity of procedures was a factor, limited time also contributed to the disproportionate use of animation and sound. Because MicroWorlds was new to the majority of students, they allotted a considerable amount of their time to exploring the capabilities of the software. Thus students had little time to devote to developing new ideas and becoming more proficient in using the many tools of MicroWorlds.

I noted in my journal how much students enjoyed exploring the tools of animation and sound. When MicroWorlds was introduced by learning how to teach the turtle, I observed that "the excitement level was extremely high. Everyone liked being the 'brain' of the turtle and experimenting with their power." The motivation described in the review of literature was apparent on such days when students explored animation and sound. Due to these observations and the unanimous desire for additional time for the projects, I think the restricted time that students had to explore the new avenues of communication prevented them from incorporating more multimedia tools in their work.

Each project revealed the diverse backgrounds, interests and skills of each student. Diversity, obscured in the text, vividly emerged with the multimedia tools. Nondescript words and themes were quickly diffused. Unique voices, family pictures, cars driving through neighborhoods, and skylines of the future replaced nondescript words and themes. The manipulation of graphics allowed Josh to convey family diversity that would have been impossible to express with written words.

Students asked questions regarding "how to do" procedures, such as cutting, pasting, cropping, drawing, altering and reconstructing material. Students did not ask me "what to do." Students had engaged ideas, and only needed guidance in implementing them. This type of thinking varied from their single media work in which they said the hardest part was thinking of ideas. In MicroWorlds students participated in the intellectual development that John Sculley (1993) describes as an "active, inquiring dialogue with the world, a personal journey of curiosity and discovery" (p. 38).

Peer collaboration increased in the lab despite students' survey responses. My journal details this in the issue of classroom management. "It's great to see the kids helping each other but it is hard to have them getting out of their seats. They're dying to share their work and help each other but it's too chaotic to have them walking around!" Students may perceive peer collaboration as a negative behavior and therefore not wanted to admit to participation.

Difficulties

In terms of determining to what extent students enhance their idea development and facilitate individual expression with multimedia tools, the major obstacles of this study were 1) the novelty of multimedia software and 2) the time limitations in the computer lab and of the study. Because only three students had previous experience with multimedia software, the majority of time in the computer lab was spent teaching students how to use the multimedia tools in MicroWorlds. With only one instructor, it was difficult to provide the necessary one-on-one assistance and conduct qualitative observations. Therefore, an additional instructor or observer would have facilitated greater insight.

Time limitations in the computer lab only allowed for students to meet twice a week for thirty minutes each. The procedures used in MicroWorlds to incorporate graphics, animation, and sound demand accuracy, which was often difficult for students to retain from class to class. Therefore, a portion of each class period was spent reviewing past learned procedures as well as learning new ones. This necessity greatly reduced the amount of time students had to exercise their creativity. Longer lab time for students would have provided students with more time to explore their capabilities. Also, time limitations of this study only allowed for two months of field work. Multimedia software is so multifaceted that students need extended time using the tools in order to become proficient in manipulating them. This necessary time could have been provided in a year-long study. Furthermore, due to the multifaceted nature of multimedia software, an alternative project to student autobiographies, for beginning users of multimedia software, could be projects structured for groups. Group projects may decrease levels of frustration that develop as a result of the multifaceted procedures of multimedia software and become compounded with time limitations.

This study would be improved by an additional instructor/observer, prolonged computer lab time for students, an extended length of study time, and cooperative group projects. With these changes to this study, students may have utilized more multimedia tools to express themselves in the publication of their writing.

Successes

As an educator and implementor of this study, I believe there are many successes. Despite many difficulties, students increased their individual expression in their work with graphics, animation, and/or animation. All students utilized at least one of these tools which at the very least enhanced the original text with illustration. Also, I consider the revision of original text in this final stage of publishing a success due to the tendency of this particular class to only write one draft when writing. Another success of this study was the frequent occurrence of "on-task" peer support in the publishing process. The peer support in this class was unique because of the lack of peer support they provide each other when writing with paper and pencil. Finally, this study was successful in that it provided students with limited computer experience some experience in communicating through a multimedia software.

Conclusion

The various tools of communication provided with multimedia software enabled students in this study to increase description, display unique perspectives, and reveal diverse backgrounds, interests, and skills that were difficult to convey in a single media format. Furthermore, in the implementation of these strategies of communication, students participated in peer collaboration, varied cognitive thinking strategies, and worked in an atmosphere of high motivation. This enhancement of idea development and individual expression resulted from utilizing the communication tools of multimedia software. These are significant reasons for teachers to use multimedia software as a tool for student communication in the learning process.

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Appendix A
With Single Media

I am doing a study for one of my classes at UVA and need your help! Will you please answer the following questions about writing your autobiographies?

What did you find to be the hardest thing about this assignment?

When writing your autobiography, how many drafts did you write?

How much time did you spend writing?

What did you consider most important when writing? Circle one

a. neatness
b. expressing your thoughts clearly
c. finishing

Did you ask your classmates for help? What kind of help?

Are you proud of your work? Why or why not?

Appendix B
With Multimedia

I need your help again! Will you please answer the following questions and return them to me. Everyone has done a GREAT job on their MicroWorlds project and should be very proud of themselves! I have loved working with all of you. You are a super class.

How did you change your autobiography on the computer?

How did you like this writing assignment using the computer?

a. I liked it very much.
b. I did not strongly like it or dislike it.
c. I did not like it.

Why?

Did you ask your classmates for help? What kind of help?

Would you have liked more time to work on your project? How much?

Are you proud of your work? Why?

Appendix C
Possible Unit Outline for Integrating MicroWorlds into the Curriculum

I. Day One: "Teaching the Turtle"
  A. Students learn how to manipulate the turtle by using its vocabulary and giving it commands.
  B. Students instruct the turtle to draw graphics, change its shape and use it as a stamp to paint icons.

II. Day Two: "Text and Paint"
  A. Students learn how to create and manipulate text boxes by changing their sizes and moving them around.
  B. Students explore the paint capabilities of MicroWorlds.

III. Day Three: "Creating the Title Page"
  A. Show students an example of an autobiography project on MicroWorlds.
  B. Students begin their projects by creating a title page for their projects.
  —include title, author, and two turtle icons that would serve as the buttons between pages, and directions for a user to explore their project.

IV. Day Four: "ClarisWorks/MicroWorlds: Cut & Paste"
  A. Students create and name pages according to the four stages of autobiographies.
  B. By opening up their autobiographies in ClarisWorks, students cut portions of the text and paste them into the appropriate pages in MicroWorlds.

V. Day Five/Six: "Entering the World of Animation"
  A. Students explore the tool of animation by using MicroWorlds' ideas and trial and error.
  B. Trial and error helps students realize the importance of choosing a "setheading" so that the turtle will animate in the desired direction.

VI. Day Seven: "Incorporating/Manipulating Scanned and Digitalized Images
  A. Students cut their scanned or QuickTake pictures that are in ClarisWorks documents and paste them into their projects.
  B. If there is limited time, student pictures can be scanned into ClarisWorks documents for them. QuickTake pictures can be taken and included in ClarisWorks documents.

Appendix C (cont.)

VII. Day Eight: "Project Time"
Students use this class to work on the aspects of their projects that they want.

VIII. Day Nine: "Adding Sound"
Students record sound and melody and incorporate them into their projects.

IX. Day Ten: "Finishing Touches"
Students use this class to add any additional touches and revisions before they share their projects.

X. Day Eleven: "Sharing Our Projects"
  A. Students have the opportunity to share their projects in an "Author's Chair" structure.
  B. Students have the opportunity to explore each other's projects.

Virtual Reality and Multiple Intelligences: Potentials for Higher Education

by Hilary McLellan

In this paper we examine how virtual reality, an emerging computer-based technology, can promote learning that engages all seven of the multiple intelligences proposed by Harvard educational psychologist Howard Gardner. We provide an overview of virtual reality technologies and an overview of Gardner's multiple intelligences. There is an extensive discussion of how virtual reality supports learning within and across seven intelligence domains. Finally, there is a review of technical and conceptual issues, concerning the implementation of virtual reality in education. Educational experiences that promote the various multiple intelligences and inter linkages are needed in the emerging electronic age more than at any previous time. *(Keywords: virtual reality, learning, education, multiple intelligences.)*

INTRODUCTION

Virtual reality is an emerging computer-based technology that offers promise as a learning tool for diverse learners. What kinds of diverse learners? Howard Gardner (1984; 1993) has proposed a model that frames learner diversity in terms of multiple intelligences. Gardner's conceptualization includes seven types of intelligences: (1) spatial intelligence; (2) bodily-kinesthetic intelligence; (3) logical-mathematical intelligence; (4) musical intelligence; (5) linguistic intelligence; (6) interpersonal intelligence; and (7) intrapersonal intelligence. Not only does virtual reality offer a tool that supports these different types of intelligences, it helps to promote synergistic interconnections among them. Perhaps the most fascinating thing that is emerging concerning virtual reality is that it has important social (i.e., interpersonal) implications.

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In this paper, we will examine how virtual reality can promote learning that engages all of Gardner's intelligences. First, we will describe virtual reality and then present an overview of Gardner's seven intelligences. Next, we will consider how virtual reality supports learning within and across these seven intelligence domains. Finally, we will discuss implementation issues of virtual reality in education, including a consideration of technical and conceptual issues.

The sense of presence or immersion is a critical feature distinguishing virtual reality from other types of computer applications.

WHAT IS VIRTUAL REALITY?

Virtual reality is a new class of human-computer interfaces. It is a medium for communication and creative expression. It is also a tool for simulation and model building. Virtual reality can be defined as a class of computer-controlled multisensory communication technologies. It can also be defined as an environment created by the computer in which the user feels present. The sense of presence or immersion is a critical feature distinguishing virtual reality from other types of computer applications. Virtual reality permits you to enter, manipulate, and travel through computer-generated, interactive, three-dimensional worlds that exist only in the computer.

Building on the fields of computer graphics, human-computer interfaces and simulation, virtual reality was devised to enable people to deal with information more easily. Virtual reality is a new type of computer tool that adds vast power to scientific visualization. Buxton (1992) explains that

> Scientific visualization involves the graphic rendering of complex data in a way that helps make pertinent aspects and relationships within the data more salient to the viewer. The idea is to tailor the visual presentation to take better advantage of the human ability to recognize patterns and see structures. (p. 27)

However, as Erickson (1993) explains, the word "visualization" is really too narrow when considering virtual reality. "Perceptualization" is probably more appropriate. With virtual reality, sound and touch, as well as visual appearance, may be used effectively to represent data. The key to visualization is in representing information in ways that can engage any of our sensory systems and thus, draw on our vast experience in organizing and interpreting sensory input (Erickson, 1993).

Virtual reality technology has been slowly developing and coalescing for at least 25 years, since Ivan Sutherland's pioneering work in the 1960s. In the mid-1980s, the technological capabilities needed to support this new medium crossed an important threshold: Improved computer graphics capabilities and computing speed came together with new human-computer interface devices such as the stereoscopic head-mounted display and the fiber optic-wired glove. The technologies underlying virtual reality came together for the first time at the NASA Ames Lab in Silicon Valley during the mid-1980s although there was much R & D work in computer graphics and other fields leading up to this breakthrough (Hamit, 1993). Silicon Valley continues to be a major center for virtual reality initiatives with companies such as VPL Research, Sense8, Autodesk, Fake Space Labs, and Greenleaf Medical Systems. Other major centers for virtual reality research within the United States include the University of North Carolina, the Human Interface Technology Lab at the University of Washington, and the Media Lab at MIT. There are also centers for virtual reality research in Europe, Australia, Singapore, and Japan.

Immersive virtual reality has received the most attention from the media but there are other types of virtual reality as well. The different "versions" of virtual reality include immersive virtual reality, augmented reality, projected reality, cyberspace, and telepresence. All of these ideas are similar, yet each is distinct. ***Immersive virtual reality*** involves interfaces worn by the user, such as the DataGlove™ and head-mounted display (HMD). This is a fully immersive system. A system where there is a "heads up" display (a computer graphics mounted display), such as the Super cockpit developed for the U.S. Air Force by Dr. Tom Furness, is an example of ***Augmented Reality***. Another type of virtual reality technology, ***Projected Reality***, perceives a participant's action in terms of the body's relationship to a graphic world (such as that displayed on a computer monitor) and generates responses that maintain the illusion that the participant's actions are taking place within that world. For example, in the Mandala virtual reality system, a video camera above the computer screen captures an image of the user and places this image within the scene portrayed on the screen using computer graphics. The user can interact with objects on the screen; for example, to play a drum or to hit a ball. At the National Hockey Museum, a Mandala system shows you in front of the goalie net. Another variant of virtual reality is *Cyberspace*, a global networked artificial reality made up of databases that can be visited simultaneously by many people. The word "cyberspace" was coined by William Gibson, author of *Neuromancer* (1986) and several other science fiction books about a future dominated by vast computer networks and databases. *Telepresence* is the feeling of being in another location. Adding computer-enhanced graphics to live video may make it possible to perform telepresence activities such as collaborative design and even surgery at a distance (Satava, 1992).

Adding computer-enhanced graphics to live video may make it possible to perform telepresence activities such as collaborative design and even surgery at a distance.

At one end of the technological spectrum are the full-immersion systems, which have received the most attention (and hype) from the media. These systems provide first-person interaction within the computer-generated world via the use of interface devices such as head-mounted stereoscopic displays, wired-gloves, wired-body suits, and audio systems providing binaural sound. Midway along the technical spectrum are the virtual reality systems that provide an augmented reality or a layer superimposed over the real world to highlight certain features and enhance understanding. For example, when an airplane is landing, the augmented reality system can highlight for the pilot just the controls used in landing. At the other end of the definitional virtual reality spectrum are the video-projected worlds that provide a second-person experience in which the viewer stands outside the imaginary world, but communicates with characters or entities inside it.

In immersive virtual reality, the user is placed inside the image; the generated image is assigned properties which make it look and act (and feel) real. With immersive virtual reality, you can look at the things that surround you on all sides and you can walk around in the virtual space. As you turn your head to the right inside the head-mounted display; the computer-generated world shifts accordingly so that you see the wall to the right of where you were previously looking. A user can be sitting in the cockpit of a virtual airplane, or standing in a virtual room that bears no similarity to the room he or she is actually standing in (Hall, 1990). With virtual reality, the user enters the computational space rather than merely observing what's on a computer screen and interacting with it via keyboard or mouse. Instead of keyboard and mouse, there is now a wired glove with electronic sensors and a head-mounted display with stereoscopic goggles (containing a miniature screen for each eye to create a 3-D effect) showing what would normally be viewed on the computer screen. Both the glove and the goggles are interfaced with the computer.

Now, as virtual reality technology is expanding and improving in its capabilities, and decreasing in cost, its educational potentials are coming closer to realization. Although this emerging cluster of technologies is still at a very early stage of development, it appears to offer promising possibilities in education, including education that addresses the full panoply of human intelligences.

GARDNER'S MULTIPLE INTELLIGENCES

Howard Gardner's model of multiple intelligences, introduced in his 1984 book *Frames of Mind*, articulates seven types of intelligences. A brief description of each of these intelligences is presented here.

1. *Spatial.* Spatial intelligence means the ability to think in pictures and images and the ability to perceive, transform, and re-create different aspects of the visual-spatial world. Highly spatial individuals often have an acute sensitivity to visual details and can visualize vividly, draw or sketch their ideas graphically, and orient themselves in three-dimensional space with ease. Sculptors, painters, and designers are spatially intelligent. So are people who instinctively know how to fix engines, gadgets, and malfunctioning household objects (Gardner, 1984; Gardner, 1993; Armstrong, 1993).
2. *Bodily-kinesthetic.* This is the intelligence of the physical self. It includes talent in controlling one's body movements and also in handling objects skillfully. Hands-on people who have a good tactile sensitivity and have a highly developed mastery of motion and coordination are intelligent kinesthetically. These physically gifted individuals can also make fine, delicate finger movements. This intelligence is what allows dancers, actors, and athletes to judge the timing, force, and extent of their movements (Gardner, 1984; Gardner, 1993; Armstrong, 1993).
3. *Logical-mathematical.* This is the intelligence of numbers and logic. The scientist, mathematician, philosopher, accountant, and computer programmer all possess this intelligence, which involves skill in handling long chains of reasoning. It includes the ability to reason, sequence, think in terms of cause-and-effect, create hypotheses,

and look for conceptual regularities or numeric patterns. People who possess this form of intelligence make sense out of things, from abstract numbers to the solar system (Gardner, 1984; Gardner, 1993; Armstrong, 1993).

4. *Musical.* Musical intelligence is the ability to perceive, appreciate, and create patterns of pitch and rhythm. This talent usually emerges early in life. Anyone who has a good ear, can sing in tune, keep time to music, and listen to different musical selections with some degree of discernment, possesses this intelligence to some degree (Gardner, 1984; Gardner 1993; Armstrong, 1993).
5. *Linguistic.* This is the intelligence of words. The linguistically talented have a flair for words, both spoken and written. They are usually avid readers with an impressive ability to understand and remember what they've read. People gifted in linguistic intelligence become poets, writers, scholars, politicians, lawyers, advertising experts, or teachers. People with this intelligence can argue, persuade, entertain, or instruct effectively through the spoken word. They often love to play around with the sounds of language through puns, word games, and tongue twisters. Sometimes they're also trivia experts because of their ability to retain facts in their mind (Gardner 1984; Gardner 1993; Armstrong, 1993).
6. *Interpersonal intelligence.* This is the ability to understand and work with other people. Interpersonal intelligence involves the capacity to perceive and be responsive to the moods, temperaments, intentions, and desires of others, the ability to get inside the skin of another person and view the world from that individual's perspective. People with a strong interpersonal intelligence make good networkers, negotiators, teachers, and therapists (Gardner, 1984; Gardner, 1993; Armstrong, 1993).
7. *Intrapersonal intelligence.* This is the intelligence of the inner self. It is the ability to know oneself, to identify and appropriately act upon one's own feelings (Gardner, 1984; Gardner, 1993; Armstrong, 1993).

It is possible for the normal person to develop every one of the seven kinds of intelligence to a reasonable level of mastery, although this doesn't usually happen. In our culture, the linguistic and logical-mathematical intelligences have historically been given the greatest weight, as reflected by intelligence tests and other measures of ability. But increasingly that is under reassessment, as witnessed by Gardner's model. It is especially important to note that these intelligences are inter-related. For example, a logical-mathematical intelligence may be supported by skills drawn from spatial intelligence, and musical intelligence may be supported by kinesthetic intelligence.

VIRTUAL REALITY AND MULTIPLE INTELLIGENCES

Roy Pea (1985) has suggested that a cognitive technology is provided by any medium that helps transcend the limitations of the mind, such as memory, in activities of thinking, learning, and problem solving. Written language and systems of mathematical notation (such as algebra) are the technologies that have received the most attention in this respect (since these systems are related to the two intelligences that have traditionally been the most highly valued). Computers are cognitive technologies that open up vast possibilities as a tool for communication and creative problem-solving. Beyond this, virtual reality is a computer-based cognitive technology that further extends these possibilities, opening immense vistas for perceptualization across all the multiple intelligences. As Wexelblat (1993) has said, "Virtual reality (VR) can be used to support almost any human activity. Or, stated in another way, virtual reality can be applied to almost any domain" (p. 23).

Roy Pea (1985) has suggested that a cognitive technology is provided by any medium that helps transcend the limitations of the mind.

Bricken (1991) speculates that with virtual reality, teachers can represent information in forms that are most compatible with a student's particular learning style, selecting interactivity options that match student performance characteristics. Tools for movement and manipulation within the virtual world can be configured to the physical needs of the individual and the requirements of the task. Furthermore, Bricken (1991) adds that

> VR offers teachers and students unique experiences that are consistent with successful instruction strategies: hands-on learning, group projects and discussions, field trips, simulations, and concept visualization. Within the limits of system functionality, we can create anything imaginable and then become part of it. The virtual reality learning environment is experiential and intuitive, it is a shared information context that offers unique interactivity and can be configured for individual learning and performance styles. (p. 2)

The following discussion of the educational possibilities offered by virtual reality will center around Howard Gardner's seven multiple intelligences.

Spatial Intelligence

Spatial intelligence is perhaps the most obvious area where virtual reality offers potential as a tool for learning and understanding. According to Jacobson (1993a),

> [Virtual Reality] helps us to solve problems because it helps us visualize information—it lets us view things spatially. When we look at data in space as a whole or in detail, we see its elements in association with each other or individually. It's easier to solve a problem when it's presented spatially instead of on paper or computer screen. As a result, we make judgments faster than if we viewed the data in numeric or written form. (p. 72)

He suggests that the spatial capabilities of virtual reality can support logical-mathematical understanding as well as spatial intelligence.

Although this type of virtual reality application has been developed to support scientific understanding and discovery, it has powerful possibilities in education, to help learners "see" and "feel" information and dynamic processes as never before. Virtual reality can be used to model complex phenomena. Students can use virtual reality to explore perspective, spatial relationships, and other types of relationships between variables in a variety of fields. And virtual reality is a dynamic, interactive visualization tool.

Visualization techniques that can aid us in using and interpreting data are (1) selective emphasis, (2) transformation, and (3) contextualization. All of these strategies are possible swiftly and interactively with virtual reality to support applications in many fields, including engineering, medicine, architecture, and investment analysis. All of these applications can be used in education as well as in professional practice, taking advantage of, and developing, spatial intelligence.

Virtual reality can be used as a data visualization tool. For example, Metaphor Mixer is an application designed by Maxus Systems International that has been developed to help stockbrokers visualize and analyze financial data (Hamilton, 1992). In this application, there is an ocean of icons representing different stocks, with rising and lowering rates. Here, the behavior of the icons, such as blinking and spinning, represents different kinds of patterns. It is possible to move in close to look at information in detail. Ideally, this will permit Wall Street to represent much more information graphically in a way that is accessible to human analysts. Some pension funds, including TIAA-CREF, have started to use this visualization tool. This type of application, designed to enhance the understanding of experts within a field, can be adapted to educational applications for novice learners. Here again, spatial intelligence is used to support logical-mathematical intelligence.

Virtual reality can also be used as a spatial design tool in architecture, interior design, set design, art, product design, engineering, city planning, archaeology, dance choreography, and other fields. For example, "architectural walkthroughs" are possible for architects—and their clients—who want to get a first-hand feel for the spaces they design, before the buildings are actually built. Sitterson Hall, the computer science building at the University of North Carolina at Chapel Hill, was designed—and revised—in virtual space with architectural walkthroughs before construction began. This virtual walkthrough of Sitterson Hall permitted the architect to observe that people felt one corridor in the building was too narrow; the corridor was enlarged in the final design.

Virtual reality can also be used as a spacial design tool in architecture.

As it turns out, such an application enhances communication between architect and client. Since the architect is likely to possess a much greater spatial intelligence than the client (or at least a more deeply trained spatial intelligence) the client often is at a loss to understand two-dimensional representations (i.e., blueprints) of a three-dimensional space. Once the client can walk through the 3-D plan via virtual reality, the architect and the client can come to a much better understanding. Another example is the architectural "roll through" application for wheelchair-bound clients that was developed by Prairie Virtual Systems of Chicago so that handicapped individuals could make sure a building design met their access needs (i.e., counters and cabinets are at a level compatible with the wheelchair, bathrooms are large enough to fit the wheelchair) before the building is actually built. Interestingly enough, with this application, the architect can gain greater insight into the client's viewpoint (interpersonal intelligence) by practicing the wheelchair roll through personally. Thus, spatial intelligence is enhanced, in tandem with interpersonal intelligence.

In what is probably the most fully developed walkthrough application to date, Mitsubichi has collaborated with the virtual reality company VPL Research to develop the "virtual kitchen." In Japan, consumers can select a kitchen with the appliance they want by specifying the measurements of their kitchen and then putting on the VPL DataGlove™ and head-mounted display to try out different models, colors, and configurations of appliances. After the virtual exploration, consumers make their selections, and, a short time later, the real kitchen is actually delivered and installed, based on their design choices in the virtual kitchen.

The automobile and aviation industries, as well as other industries, are adapting virtual reality techniques to speed and improve product design and testing. For example, at the NASA Ames Lab, a virtual reality visualization of airflow dynamics has been developed to study wind flow on the surfaces of new aircraft designs. Their virtual wind tunnel application permits engineers to analyze three-dimensional field flows on airplanes and space vehicles more flexibly and interactively than is possible with the enormous real wind tunnel that it supersedes. (Incidentally, the real wind tunnel requires the electrical power comparable to what is needed by a small city when in operation.)

These design applications can be adapted to education. In addition to preparing blueprints and 2-D sketches of their designs, architecture and engineering students can prepare "virtual" models to show to their teachers. Such models offer the potential to develop and refine learner's spatial intelligence in powerful ways.

Recently, Intel and other leaders in the virtual reality industry have made this new technology available to artists—individuals gifted in spatial intelligence—in the belief that they will provide valuable assistance in envisioning, testing and demonstrating the capabilities of this new tool. An exhibit of virtual reality art was held at the Guggenheim-Soho Museum in New York City in November 1993.

Virtual reality can also be used as a spatial visualization planning tool. For example, at the University of North Carolina at Chapel Hill a virtual reality application has been developed that helps physicians plan how to position the beams of radiation used in cancer therapy. In this application medical images, representing the organs within the human body in three dimensions, permit physicians to conveniently practice setting up two intersecting radiation beams so that they target the tumor, minimizing the radiation impact to surrounding healthy tissue. Virtual reality applications provide aspiring doctors with the opportunity to practice skills meaningfully, in a contextually rich setting, before they practice on actual human patients. This kind of virtual reality planning application can be applied in a number of fields.

Benjamin Woolley (1992) has identified a connection between virtual reality and the notion of memory palace, a technique for aiding the memory that was very important in ancient Greece before a written language was available. The memory palace technique used spatial intelligence to support linguistic intelligence. By mentally walking through an imaginary space, a storyteller was able to recall a sequence of ideas. Woolley suggests that navigation in virtual space can be used as a mechanism to reinforce other kinds of learning. Exploring "virtual space" as a means of enhancing memory and linking ideas may provide a valuable metaphor for virtual world designers to consider, in order to capitalize upon spatial intelligence to support learning in other intelligence domains.

Navigation in virtual space can be used as a mechanism to reinforce other kinds of learning.

Bodily-Kinesthetic Intelligence

Bodily-kinesthetic intelligence involves both movement and the sense of touch. Virtual reality can support both aspects of this physical intelligence.

For example, in terms of the sense of touch, the University of North Carolina at Chapel Hill has developed an immersive virtual reality system that includes both a visual display and a force feedback arm for tactile cues to help chemists explore the force-fields that bind molecules together or cause them to repel one another (Rheingold, 1990). Atoms and molecules are too small to be seen, so a three-dimensional model is created that incorporates the characteristics of these invisible phenomena for purposes of experimentation. In addition to three-dimensional graphics that help chemists see the microscopic molecules at an enlarged scale, a force feedback arm simulates feedback pressure representing the force-fields of attraction and repulsion between different molecules. Under these conditions, scientists can better sense where to dock individual molecules into a combination of molecules, based on mutual attractions and repulsions. In sections of two, molecules repulse each other, they won't combine well, but if they attract, one can be docked to the other to form links in a chain of molecules. This research aids biochemists in their search for targets on protein where they can attach drugs.

The scale of the virtual chemistry model can be changed from something you hold in your hand to something the size of a room.

The application mentioned above supports both spatial and kinesthetic intelligences, linking them together to enhance understanding. It is readily applicable to educational applications, where students could practice combining different elements to "see" and "feel" how they interact at a molecular level. The scale of the virtual chemistry model can be changed from something you hold in your hand to something the size of a room. The change in scale, together with the different resistances calibrated for each type of molecule, articulates and highlights the force-fields and the attraction and repulsion between molecules. These perceptualization options offer tremendous potential to invoke both kinesthetic and spatial intelligences to promote learning.

Several experimental virtual reality systems offer tactile feedback. One example is the Sandpaper application, controlled by a joystick, which simulates the feel of different textures, including different vicosities (thicknesses) of liquids as well as roughness and bumpiness. This application was developed by Margaret Minsky at the MIT Media Lab. Another example is an adaptation of the DataGlove™ developed at the Human-Machine Interface Laboratory at Rutgers University (Adam, 1993). With this application, small pneumatic micro cylinders are attached to the glove from the palm to the fingertips with Velcro to produce force feedback, like the feeling of resistance when one crushes a soda can.

Concerning the movement aspect of the kinesthetic intelligence, virtual reality can provide users with the opportunity to practice activities involving fine motor skills using the hands, while obtaining highly precise and sophisticated feedback on performance from the computer system that underlies the virtual environment. Such a virtual reality learning system permits repeated practice of skills that may be difficult to practice in the real world or through any other training method. And the feedback component offers enormous potential for many applications.

Musician Yo Yo Ma uses virtually reality to record the movements of his bow while playing the cello (Markoff, 1991). He can examine differences in his bowing during several performances of the same piece of music. First, he determines which performance is the best (using his exceptional musical intelligence). Then, he observes his bowing technique to see how it contributed to an outstanding performance. Finally, he can use the information to replicate the desired level of performance. Thus, kinesthetic intelligence is used to support musical intelligence.

Kinesthetic intelligence applications are also adaptable to other educational purposes. Greenleaf Medical Systems has developed an application of the VPL DataGlove™ for William J. Morgan, the associate team physician for the Boston Red Sox, that records and analyzes fast balls thrown by four team pitchers, including Roger Clemens (Hamilton, 1992).

> Hurling a 100-mile-per-hour fastball down the middle is a special skill worth analyzing. But a big-league pitcher's arm, wrist, and finger movements change so rapidly that they're almost impossible to dissect. This thwarts efforts to learn from good pitchers—or to figure out what's wrong when they have injuries or slumps. (Hamilton, 1992, p. 98)

This application of virtual reality as a data gathering tool for performance feedback is similar to Yo Yo Ma's musical application described above. Greenleaf's adapted version of the DataGlove™ offers a wealth of possibilities in sports, medicine, and other fields.

NEC has created a prototype for a virtual reality ski training system. Wearing a head-mounted display, the learner stands on two metal plates with ski poles in hand and practices various maneuvers. As the learner views the virtual slope, the plates move to create the sensation of traveling over hills and down slopes. The learner learns how to use the balance of his or her weight to move within the virtual ski environment. A sensor estimates the stress/relaxation rate by monitoring the flow of blood through a finger, and then the system adjusts the difficulty of the virtual terrain in response. The skier's distribution of weight between both feet is also monitored, including both the front/back position and the right side/left side. NEC foresees other future applications of this type of technology in sports, education, health care, and rehabilitation.

The Mandala projected reality system was developed by two Canadian performance artists to support their work, which involves both kinesthetic and musical intelligences (Wyshynski & Vincent, 1993). Applications now extend beyond performance art and entertainment. Mandala can now be found as an interactive display in museums and as a musical-kinesthetic tool in rehabilitation centers (Treviranus, 1993). It can be used as a medium for telecommunication. The Mandala virtual reality system supports kinesthetic intelligence as well as interpersonal and musical intelligences and offers promise as an educational tool.

Virtual reality "is not a simulation of reality, it is a superset of reality, it is more than reality."

Logical-Mathematical Intelligence

Logical-mathematical intelligence involves the ability to reason, sequence, think in terms of cause-and-effect, create hypotheses, and look for conceptual regularities or numeric patterns: making sense out of things. Bricken (1991) suggests that with virtual reality, we can teach meaning and sense-making through experience and learning in context, then teach the symbolic abstraction of our experiences (such as algebra). One example of how virtual reality can be applied to creating an experiential learning environment is the Virtual Physics Laboratory, a virtual reality application developed by researchers at the University of Houston and NASA's Johnson Space Center, under the direction of R. Bowen Loften. In this lab application, students can experiment within a simulated physics laboratory, changing the force of gravity and seeing how this changes the behavior of objects (such as bouncing balls) within the lab environment.

Bricken (1991) speculates that the computer is an ideal tool for manipulating symbolic abstractions. She suggests that instead of teaching the abstraction, we can teach the learner how to use the virtual reality tool, providing a natural interface between the physical world and the logical-mathematical abstractions that we use to encapsulate processes and interactions. Bricken explains that virtual reality "is not a simulation of reality, it is a superset of reality, it is more than reality" (p. 3). Virtual reality permits us to model reality, but it also permits us the freedom to escape the bounds of reality, for example in the physics application, where gravity can be set at "unreal" levels for purposes of experimentation.

Bricken suggests that virtual reality applications such as the Virtual Physics Laboratory can teach active construction of the environment.

> Data is not an abstract list of numericals, data is what we perceive in our environment. Learning is not an abstract list of textbook words, it is what we do in our environment. The hidden curriculum of virtual reality is: make your world and take care of it. Try experiments, safely. Experience consequences, then choose from knowledge. (p. 2)

Virtual reality offers the potential to link logical-mathematical intelligence to the other intelligences: spatial, kinesthetic, etc., and also to explore firsthand the process of exploration and sense-making, which are at the heart of logical-mathematical intelligence. Lantz (1992) speculates that with virtual reality, highly technical concepts and information can be presented intuitively, allowing the user to go beyond "book knowledge" and actually develop a "feel" for advanced concepts and relationships in a very short time.

Musical Intelligence

Musical intelligence, the ability to perceive, appreciate, and create patterns of pitch and rhythm, is central to musician Yo Yo Ma's application of virtual reality discussed earlier. Yo Yo Ma is working with researcher and composer Tod Machover of the MIT Media Lab who has developed a "hyperinstrument," in this case a cello is augmented by a computer. The computer is linked to sensors on the performer's bow and bow hand. The computer records each movement the performer makes as he plays. Gesture can be as subtle as the way a performer holds a bow or strikes a note on the piano. It is the essence of what makes each live performance different from all others (Trubitt, 1991; Markoff, 1991).

Machover has strong opinions about the way technology is used to transform musical performance. He believes that new technologies such as virtual reality should not only enhance the enjoyment of music, they should also augment traditional musical skills. The hyperinstrument application is an example of how virtual reality technology can help achieve both of these goals, supporting musical intelligence.

Virtual reality makes it possible for musicians to explore music tailored to the human binaural auditory system (humans have two ears) with 3-D audio. This adds rich dimensions to musical composition and listening. Slip on a pair of headphones, and the sound seems to be coming from all around (Wheeler, 1991). This can be used to reinforce spatial understanding, in addition to supporting musical intelligence since sound is an important cue for orienting ourselves in space and for obtaining a sense of presence (Laurel, 1992).

In one application of virtual reality, dancers can control the location from which the sound appears to come through their gestures when linked to 3-D sound systems (Gehring, 1992). This adds to the richness of their performances and links kinesthetic and musical intelligences.

The "Very Nervous System" is a type of virtual reality application that creates a reactive musical environment. Sounds from an interactive computer-based musical composition are triggered by movement in front of the computer. The response is calibrated to the location of the movement and the speed and intensity of the movement. For example, a slow, langorous wave of the arm evokes a different sound than a swift arm wave. This application and others like it are being used as a musical tool and also as a rehabilitation tool (Warner, 1992; Treviranus, 1993). Individuals with serious injuries who are in rehabilitation often have difficulty finding the motivation to carry out simple, monotonous movements such as arm lifts over and over again. A responsive musical environment provides motivation and an opportunity for creative exploration: what sounds will result from different movements? Thus, rehabilitation patients have a captivating form of "air guitar." Once again, kinesthetic intelligence is linked to musical intelligence.

Linguistic Intelligence

It is important to keep in mind that virtual reality is a medium of communication that supports many types of communication. Language is central to human communication. Visualization, perceptualization, should enhance and extend communication, not truncate it.

Wexelblat (1993) links computer-supported cooperative work and groupware with virtual reality. Indeed, it is easy to see how these applications support telepresence, the feeling of being in another place. Cyberspace, one component of virtual reality, encompasses all communications via computer networks, including electronic mail and computer databases. Groupware permits collaborators at different locations to communicate verbally via video windows on the computer screen and also to work collaboratively on creating and revising text documents interactively. This application supports linguistic intelligence as well as interpersonal intelligence.

Successful groupware systems should allow people to cooperate by overcoming barriers of space and time. People in many types of work need to cooperate on work that includes text (and perhaps text combined with pictures). Rensselaer Polytechnic Institute in Troy, New York, is one university that is exploring a computer network system, BBN Slate (it's not really groupware), to support collaborative communication between professors and students (Miley, 1992). This type of application promises to expand within higher education and elsewhere. Electronic mail is promoting a revitalization of written communication that has been in decline since the advent of the telephone (Tuman, 1992; Rheingold, 1993). All of these types of Cyberspace applications support linguistic intelligence.

Successful groupware systems should allow people to cooperate by overcoming barriers of space and time.

Andrew Connell (1992), of the National Advanced Robotics Research Centre, Salford, England, reports that in Newcastle, England, West Denton High School is pioneering the use of virtual reality technology, including an application for the foreign language curriculum. An Intelligent City, based on part of a French city, is one virtual environment that is under development. It includes support material, introducing the user to the city, and a set of tasks such as locating a restaurant, buying a specific item, and using the public transport system.

Although this is an exciting application, it requires sophisticated speech processing for synthetic agents within the virtual world to achieve its fullest potential. Linking virtual reality and artificial intelligence remains an area that needs more development (Laurel, 1992). Virtual reality entertainment systems will probably lead the way; for example, the Legend Quest game includes an adaptive AI component that "learns" from the performance of each player, shaping each new game that includes that player accordingly.

Interpersonal Intelligence

Virtual reality applications for multiple participants are emerging that suggest virtual reality can support interpersonal intelligence in powerful ways. These applications include groupware and computer-supported cooperative work, some educational applications, and also some entertainment applications that have emerged, for example BattleTech and Legend Quest. The notion of computer-supported cooperative work is indicative of a broad trend toward computer applications that support social—interpersonal—use of computers, especially in the areas of research and development and education. Virtual reality is a part of this trend, which underscores the importance of interpersonal intelligence.

Virtual reality underscores the importance of interpersonal intelligence.

Humans are social creatures. They don't want to visit Cyberspace by themselves; they want to share what they see and feel and think—either during the experience, or afterwards. The BattleTech entertainment system, where four players in individual simulator pods play out the computer-controlled game scenario together as a team, features a briefing session before the actual virtual reality experience (the actual game itself lasts ten minutes) to orient new players, aid the sense of immersion in the alternate world of the game, and permit experienced players to strategize coordination (Jacobson, 1993b). The game is designed so that cooperation is the most effective strategy for winning the game. Heeter (1992) reports that most players value the opportunity to play with other people, rather than merely playing against a computer-controlled component. Players report that learning to cooperate effectively is the most difficult skill to master—requiring over fifty games to learn—but is an extremely valuable skill within the context of the game. BattleTech's co-creator, Jordan Wesiman reports that people who play on a team together discuss the game afterwards and often go on to become real world friends (Jacobson, 1993b). In the Legend Quest game, an immersive entertainment system for several players, which is derived from the Dragons and Dungeons role-playing game, players have formed guilds that meet to plot strategy based on understanding the strengths and weaknesses of the various characters that it is possible to play. These entertainment systems may offer some inspiration for instructional virtual reality applications intended to support interpersonal intelligence.

McLellan (1991) describes how virtual reality can be used to assist learning that involves a strong social component within the context of the situated learning model. One example of how virtual reality can support interpersonal intelligence is a virtual environment training application for airline pilots: Line-Oriented Flight Training (LOFT). Interpersonal intelligence is the central goal of this application. The pilots must gain experience working together to come to terms with different sets of problems in order to build the skills necessary for collaborative teamwork and coordination. These sets of problems could cascade into a serious crisis if not handled effectively with coordination between crew members. Reflection and discussion are scheduled into the training after the simulated flight is over, when an instructor sits down with the crew to critique the pilots' performance.

Interpersonal intelligence is vitally important to collaborative discoveries in the arts and the sciences; virtual reality is a new tool for discovery.

Related to the dramatic enactment in the pilot training program, Brenda Laurel (1990), a virtual reality pioneer whose background is in both the theater and computer game design, suggests that the principles of effective drama can be adapted to the design of interactive systems, such as virtual reality. Drama is a social phenomenon, performed before an audience, that showcases interpersonal and intrapersonal intelligences. The audience becomes the instructor, providing coaching and criticism of the performance until the learner "gets it right." Other members of the training team also serve as an audience for each other in a learning context that emphasizes interpersonal intelligence, i.e., understanding and working effectively with other people.

Interpersonal intelligence is vitally important to collaborative discoveries in the arts and the sciences; virtual reality is a new tool for discovery. In his book *Shared minds: The new technologies of collaboration,* Michael Schrage (1990) says:

> All collaborations rely on a shared space. It may be a blackboard, a napkin, a piano keyboard, a rehearsal room, a prototype, or a model. Independent of whether the collaborators are artists, scientists, professionals, managers, or mechanics, collaborators are inevitably drawn to a shared space to share the ideas and insights that will solve the problem or achieve the task. The shared space becomes a partner in collaboration. (p. 153)

The computer, and in particular virtual reality, provides a shared space that eliminates barriers of distance and offers a rich set of communication tools and serves as another example of how virtual reality can support interpersonal intelligence.

The JASON Project, which features telepresence field trips, furnishes still another example of how virtual reality can support interpersonal intelligence (EDS, 1991). The JASON Project transports thousands of North American students via satellite to sites where a team of scientists is uncovering historic discoveries and, through sophisticated data links, allows these students to become hands-on participants. At the interactive down link sites for the JASON Project, three enormous video monitors give students a window on the action of scientific discovery as it unfolds. The focus of the research is JASON Jr., a 200-pound remotely operated vehicle (ROV) equipped with video cameras that can explore thousands of feet below the ocean's surface. Students at the down link sites can talk to the scientists. Some students have the opportunity (very briefly) to operate JASON Jr., directing its movement single-handedly, by means of a joystick and digital data link. Scientists are able to interact with students individually, as well as exchange questions and answers among the entire group. This application highlights linguistic intelligence as well as spatial and interpersonal intelligences. Steering the remotely operated vehicle involves a kinesthetic component.

Galloway and Rabinowitz (1992) have developed a telepresence system with 60 locations throughout the world that uses video and computers as an interactive communications medium to pioneer virtual space. In the "Electronic Cafe International," based in Santa Monica, California, people from different locations are electronically combined, using satellite linkages, into the same real-time virtual space. The Electronic Cafe International has sponsored dance projects, "Earth Day Global Link '90," and other collaborative creative initiatives that include connections and teleperformances by participants across the globe in real-time. The Electronic Cafe International is event-driven; arts groups are encouraged to produce events. This application supports interpersonal intelligence (as well as kinesthetic, musical, linguistic, and spatial intelligences) while dissolving the barriers of distance.

The developers of Habitat, a networked graphical virtual world created at Lucasfilm, were surprised at how quickly the users—even in this primitive electronic space—began to develop their own culture, their own institutions, their own laws (Morningstar & Farmer, 1991). For example, special forms of greetings emerged (this is similar to the language of sideways smiley faces used to enhance interpersonal communication with electronic mail). Interpersonal intelligence is alive and well in Cyberspace.

Intrapersonal Intelligence

Intrapersonal intelligence, the intelligence of the inner self, can be enhanced by playing with the concept of personal identity, including role-playing. Several role-playing applications of virtual reality have been developed, highlighting some exciting possibilities.

Several role-playing applications of virtual reality have been developed, highlighting some exciting possibilities.

The Legend Quest game described earlier is one example of a role playing application. Legend Quest players must get to know the advantages and disadvantages of the characters they play very thoroughly if they hope to win the game (winning is very tough). There's a total of eighteen characters in Legend Quest, each with distinctive advantages and disadvantages. This form of virtual role-playing may be a very compelling kind of experience that only virtual reality can offer. In Legend Quest, players' voices are electronically transformed to match the character, adding to the sense of immersion and engagement.

VPL Research, the company that first commercialized head-mounted displays and wired gloves, has conducted informal experiments where users within a virtual environment could play with becoming different creatures (for example, a lobster), viewing the virtual world through the eyes of his or her creature (Sheridan and Zeltzer, 1993). Users play the roles of different creatures within a virtual world, racing, wrestling, and embracing each other. In addition to viewing the virtual world through the eyes of their respective creatures, users can choose to view the virtual world through the eyes of a creature that someone else controls. Biocca suggests that what sets these VPL experiments apart is the attempt to play with the concept of personal identity. In a dialogue with virtual reality pioneer Jaron Lanier (who founded VPL), Biocca (Lanier & Biocca, 1992) comments:

> Within this playfulness lies a very interesting concept in which the use of this technology is explored. Not only can virtual reality be used to experience another identity—real or fantasized individuals—but it

> offers the potential experience of other shapes, forms, and objects, other modes of the self. (p. 161–162)

Sheridan and Zeltzer (1993) state that

> [The VPL role-playing experiment within virtual reality] has profound implications for a variety of uses—including entertainment, product design, scientific research, even psychotherapy—in that it could someday allow us to experience a variety of physical and social interactions not only through our own eyes but those of another. (p. 28)

VIRTUAL REALITY IN EDUCATION: IMPLEMENTATION ISSUES

The practical potential of virtual reality is still under exploration, but it appears to offer many educational potentials that support all seven of Gardner's panoply of multiple intelligences. Furthermore, virtual reality offers applications in many disciplines, including medicine, rehabilitation, geology, chemistry, physics, aviation, space science, robotics, business, architectural and interior design, city planning, product design, law enforcement, entertainment, the visual arts, music, dance, and education. In addition, virtual reality offers many possibilities as a tool for nontraditional learners, including the physically disabled and those undergoing rehabilitation who must learn new communication and psychomotor skills.

Virtual Reality, the latest development in the world of computers, offers great promise, although it is still in its infancy. It is important that educators understand that serious technical and conceptual issues must be addressed before the potential of virtual reality for education can be realized. For any educator who wants to use this technology, it is critical to understand that the current virtual reality technology is far from mature and that the necessary educational research for its optimum learning use is only now beginning to be conceptualized and carried out (McLellan, 1991; Helsel, 1992; Regian, J. W., Shebilske, W. L., and Monk, J. M., 1992; Bricken and Byrne, 1993).

TECHNICAL ISSUES

Laurel (1992) reports that there are two types of technical issues affecting the development of virtual reality. These include: (1) issues involving the technical capabilities that we know are necessary, which present problems for which we can see possible solutions, and which can benefit from progress made in increments over the past few years (i.e., image generation and 3-D audio); and (2) issues involving technical problems where we don't know what the solution might be or what direction to take to discover the solution. According to Laurel (1992), the second class of issues includes: (1) virtual locomotion—movement in virtual space; (2) the sense of touch in virtual space, both in terms of force and mass; (3) smell and taste; and (4) speech processing. There are many promising projects exploring all of these areas, but no one effective "right" solution has emerged.

It is critical to understand that the current virtual reality technology is far from mature.

Laurel explains the importance of speech processing:

> In a virtual world you want to be able to talk to and be understood by synthetic characters, and those characters must be able to generate speech back. If we constrain things into cartoon-quality stuff, we can start to use speech today, but doing serious discourse and understanding is beyond our reach right now. (p. 287)

Laurel's emphasis on speech processing highlights the importance of linguistic intelligence in virtual reality. Laurel further reports that work to address these technical issues is constrained by pragmatic concerns such as the cost of the equipment and, concomitantly, access for creative users who might help to solve these design problems. Thus, it is vital to develop system configurations and applications that are affordable.

Technical issues that can probably be solved incrementally include human factors issues: reducing the size and weight of the head-mounted display interface and designing interfaces that become invisible. Still, another issue is to improve the speed of tracking user movements and correspondingly, increasing the image update rate when the user moves.

Improving graphics resolution is a continuing quest of virtual reality designers. However, Laurel (1992) suggests that it is more important to focus on "sensory combinatories" optimizing the combination of the media channels so that the sum is more than the parts. According to Laurel, sensory combinatories "concerns not so much the resolution and bandwidth as it does with putting sensors together properly in multi-sensory environment" (p. 287). One example is the role of audio. In computer games, high-resolution audio has the effect of convincing people that the game's graphics are higher resolution, too. Unfortunately, this synergistic effect does not work in reverse; high-resolution video does not create the illusion that audio has improved.

Laurel suggests that audio pulls us along in terms of involvement and immersion:

> …pulling stuff out of the imagination of your user to achieve a very deep level of participation. It turns out that audio is a whole lot better at that, in general, than video. When you create an audio-intensive environment, the effect tends to work better. (p. 289)

Audio also has other advantages. According to Laurel (1992),

> Audio is much better than video at creating a sense of real space. Multisensory photo-realism is a false Grail. The computer graphics world is obsessed with resolution, and specifically, with photo-realism. In virtual reality it translates into an obsession with turning up all the knobs—video, audio, smell, touch, taste. There are a couple of things wrong with that attitude. McLuhan suggested that media that saturates your senses also cauterizes your imagination. (p. 287)

At this point, virtual reality technology is still fairly primitive. The motion of images is jerky, for example, and the computer-generated objects look more like cartoons than the real thing. The quality of the computer graphics in these systems is poor when compared to the photo-realism now possible on high-resolution color monitors (Wheeler, 1991). Virtual reality technology requires vast quantities of data to portray a complex, dynamic three dimensional image and to revise the image every time the user's head moves. However, computer memory capabilities are improving rapidly. Research is underway that will enable the next generation of computer chips to support virtual reality (Teixeira, 1992).

Conceptual Issues

Concerning conceptual issues, a cohesive design metaphor is needed, which includes cohesiveness between the different sensory systems similar to the desktop metaphor for word processing and related applications. As Laurel (1992) explains, "Engagement is only possible when we can rely on the system to maintain the representational context" (p. 115).

Another conceptual issue is: What do you (or the learner) do once you're inside the virtual world? Designers need to determine how to structure the experience to support learning. McLellan (1991) suggests that the situated learning model provides one possible structure. The Virtual Physics Lab offers another model for instructional design, based on constructivist learning. Of course the learning goals for each application must provide a starting point.

McLuhan suggested that media that saturates your senses also cauterizes your imagination.

Thurman (1992, speech) advocates that we focus on instructional strategies, because "device dependently is an immature perspective that almost always gives way to an examination of the effects of training on learners, and thereby fine-tune how the medium is applied." Thurman also recommends that virtual reality researchers should examine simulation as a model since there is a large body of research available in that area to inform the development of virtual reality applications for learning. Simulation and simulator-based training are major precursors to virtual reality.

Bricken (1991) claims that the significance of virtual reality to education may lie in its broad implications. By making virtual reality tools and environments available to educators, it may be possible to discover more about the very process of learning. Further, by participating in the development of virtual reality, educators can guide the growth of the technology and perhaps influence the course of educational change.

Still, Helsel (1992) recognizes that, although virtual reality holds much promise for the learning process, it also holds many questions. How do we ethically and accurately duplicate/create another person, time period, or place? How does the human perceptual system process and best utilize visualization and sonification data generated by virtual reality? Educators must answer (and ask) these questions—and many, many more—before the promise of virtual reality as a learning medium is realized.

In sum, how do we harness this powerful new technology to support learning? Because it emphasizes multisensory, multidimensional information-presentation capability, virtual reality offers a range of representational and presentation tools, bridging many disciplines and providing a powerful synergistic learning tool. Laurel

(1992) speculates that in the electronic age that is swiftly emerging, innovations such as virtual reality are advanced by people who have the right sets of skills. These skill sets are diverse and eclectic, more so than at any previous time. Laurel calls the people who possess these skill sets "fusion craftsmen."

Educational experiences that promote the various multiple intelligences and the inter-linkages among them will promote the emergence of such fusion craftsmen, people who are gifted—and educated—across a variety of intelligences. Virtual reality is potentially a powerful tool to support the education of fusion craftsmen who are skilled in the full panoply of intelligences. And virtual reality may be able to support learning experiences that take advantage of the inter-relatedness of the different intelligences. This inter-relatedness must be acknowledged in the design of optimum learning experiences.

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Section 3

Making Technology Work

Getting technology in place and setting up necessary training to use it are always primary issues; but, if technology is to truly deliver on its promise as a powerful tool for teaching and learning, we must use it effectively and promote new and promising applications among ourselves. Each of the articles in this section addresses those goals.

Dawn Morden's article on using the Internet as an electronic "crossroads" to the world of learning is based on her work as a gifted-talented teacher. Realizing the importance of connecting students to authentic learning experiences, Morden talks about using the Internet with such issues as culture, history, and geography. She involved her students in rich, interdisciplinary activities (poetry, interactive software, Web surfing, cooperative planning, and exhibiting activities). Typical textbook activities, Morden found, led to poor recall and lack of interest. Her "crossroads" project, on the other hand, brought high levels of motivation, participation, and achievement.

Much has been written about the emerging "global village," but few technology projects have addressed what it takes to make it happen. Scardamalia and Bereiter's article, "Engaging Students in a Knowledge Society," describes their comprehensive effort to build such a network in Canada. Their telecommunications project emphasized cross-school research and addressed issues such as scalability (can small-scale projects go systemwide?) and sustainability (can the model survive without heroic efforts?). As with other successful efforts, they made wise use of local help from the community, especially from higher education. Scardamalia and Bereiter describe their model as one of "mutually reinforced high achievement," where students work with real-world ideas and extend them over a lifetime. Those are laudable goals and worthy of cloning.

Lastly, Bennett and King's article, "The Saturn School of Tomorrow," describes the challenge of planning and building a new school with the primary focus of "education for each student." This goal was obtained through a personal learning plan designed by students, with help from parents, teachers, and advisors. This article describes the authors' efforts to make a major break with schools as they have been and invent a new school as it might be: one where students learn to take greater responsibility for their own learning, and educators give them the help and tools they need to do it. Bennett and King found that "what if" is an important question for educators to ask, and that real change needs a chance to be successful. Eight years later, and not without several challenges to survive, the school is still looking for new and better ways to be a school of tomorrow . . . today.

Susan Hixson's article, "It's elementary! Internet in a K–5 School," outlines an Internet project at her elementary school in Arizona. To make it happen, the school staff first worked up a sensible plan. They built strong support for it at the district level and were fortunate to have an innovative and supportive principal. Because funding agencies often help those who help themselves, Hixson's team found grant dollars outside the school. More importantly, they secured technical support from a local hardware company and help with teacher training from a local higher-education institution. The staff then worked on building in-house expertise, realizing that outside support may not last forever. The students (and the teachers) were the beneficiaries of this solid effort, as evidenced by the students' fascinating Internet projects.

Crossroads to the World

by Dawn L. Morden

Using their imaginations and the power of technology, teachers can develop an authentic curriculum that takes their students on exciting journeys of learning.

Imagine taking 23 sixth graders on a trip across Canada for several months. An arduous undertaking by any stretch of the imagination, but this is what I did last year. With the help of telecommunications, my students and I were transported thousands of miles—without physically leaving Altoona, Pennsylvania.

With Crossroads to the World, an authentic learning experience, students have the means to experience and appreciate the world's cultural, historical, and geographical differences and similarities. Basic to the project is an integration of technology and the use of an extended real-life simulation. Students simulate a trip and are involved in every aspect of the journey from planning itineraries and budgets to documenting their travels.

In addition to the Canadian trip, I have traveled with some of my 7th graders to France, Germany, Italy, Spain, Denmark, and other countries. Some teachers in my district have taken their students on journeys through Pennsylvania, Ohio, New York, and Maryland.

JOURNEYS OF THE IMAGINATION

Crossroads to the World came into being because I, like many other teachers, saw a problem and wanted to give my students more relevant, enjoyable experiences in learning. After teaching 6th grade social studies for a number of years, I noticed that my students were disinterested in the content; even many "good students" did not remember much of the material. Because they saw little relation

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between the text and their own lives, my students were not motivated to explore the ideas presented. The combination of many facts to read (the social studies textbook was huge!) and little relevancy resulted in poor retention and synthesis of the content—despite the various instructional strategies that I tried.

So, with the help of my students and Connie Letscher, a colleague, Crossroads to the World was born. Crossroads is an interdisciplinary, technology-based project that involves constructive or generative learning and which can be adapted to most any social studies curriculum. The project begins with literary models—such as excerpts from Walt Whitman's "Song of the Open Road" and *The Wild Children* by Felice Holman—to stimulate students' thinking about traveling. Students then use simulation software such as *Oregon Trail* (MECC), *Cross-Country Canada* (Didatech), and *Where in the World is Carmen Sandiego?* (Broderbund) to generate ideas for their own simulations.

> **Important to Crossroads is the fact that we can gain "firsthand" information from our faraway friends about their communities, states or countries.**

With a small grant from the Altoona Area School District Foundation and the Pleasant Valley Elementary School's association, I installed a phone line in my classroom and subscribed to *WorldClassroom*, a curriculum-based educational telecommunications network. Soon my students and I were communicating with people all over the world.

Important to Crossroads is the fact that we can gain "firsthand" information from our faraway friends about their communities, states, or countries. This year as well as last, my students have also accessed the Internet as a resource.

Of course, the age-old method of letter writing is still good as gold; with word processors, however, students can write more easily to numerous locations for travel information.

Students send both personal and business letters to other schools, chambers of commerce, tourist bureaus, and embassies.

Excitement and enthusiasm soar as students choose their travel destinations and begin to gather information about them. While collecting data, students learn about the world-opening possibilities of telecommunications, the use of databases as organizational tools, and the wonders of CD-ROM and laserdisc technology.

BON VOYAGE!

After gathering some basic information, students begin to plan their itinerary—keeping in mind that funds are not unlimited. In preparing the budget, they use a spreadsheet. During the first year of the project, my 6th graders earned money by doing class jobs or by winning games that we played to review for tests.

During their actual "travel," students continued to gather information about destinations and travel routes.

Planning is a crucial aspect of this project, as it would be in real life. My students consulted newspapers, TV, and other media for details about weather, current events, or natural disasters. Problem solving is also important. Real-life predicaments are faced as challenges, but also as opportunities to apply skills and knowledge.

Can party planning be one such challenge? Yes, but also a wonderful opportunity. Before their journey, my 6th graders planned a fantastic bon voyage party for themselves, complete with invitations to friends and family created using *Print Shop* (graphics software from Broderbund), an agenda, refreshments, decorations, and entertainment—including a demonstration of the technology-based simulation models.

The fact that my students and I were very *involved* in this real-life simulation was brought home when two of my young students, Jessica and Mandi, asked me about bringing their mothers along on the trip. "No problem," I said, "as long as you can 'earn' the money to pay for them!"

During their actual "travel," students continued to gather information about destinations and travel routes. Telecommunications can be invaluable at this time, particularly if there is good interaction between the travelers and their friends at the destination. Because this is not always possible, however, students also rely on CD-ROM, laserdiscs, and more traditional resources.

I ask my students to document their travels in several ways. First, they keep a daily log. My 6th graders recorded their entries in notebooks; last year, however, several 7th graders suggested keeping their logs on audiotape. It was fun for me to listen to some of the logs instead of reading all of them. This alternative is super, depending on the objectives and rational for the log.

Students also documented their travels with two types of scrapbooks: a traditional scrapbook and a HyperScrapbook, which includes not only text but also graphics, animation, and sound. Using *HyperCard* on the computer and a laserdisc player, we accessed "Regard for the Planet," which includes 50,000 photographs by Marc Garanger. This laserdisc provided us with some beautiful scenery of the countryside during our journey to Halifax, Nova Scotia. We also saw New York City and more.

Next year my hope is for students to include their own "home movies" using the *QuickTime Starter Kit*, which includes *QuickTime* (a Macintosh software extension), as well as programs that allow them to play, edit and create movies on the computer from a video source, such as a video camera.

TECHNOLOGY'S PROMISE AND POWER

With Crossroads to the World, my students are still learning the same information as in their textbooks—but in a more engaging way. They are involved, they are planning, they are creating. The promise of technology is so powerful! It is part of an authentic learning experience because it is part of real life, *now!*

Next year I will again travel and learn with another group of students, and because the world is different today than it was last year, we still face new challenges and new learning opportunities. Crossroads will continue to evolve.

My colleague and I developed Crossroads to the World to mirror real life and to bring students closer to one another and the world around them, thus increasing their chances for understanding and providing the way to a better future. This *is* one of the powers of technology.

Author's note: Crossroads to the World received one of the first Pioneering Partners grants from the Council of Great Lakes Governors for its innovative use of technology.

Engaging Students in a Knowledge Society

by Marlene Scardamalia and Carl Bereiter

Imagine a network of networks—people from schools, universities, cultural institutions, service organizations, businesses—simultaneously building knowledge within their primary groups while advancing the knowledge of others. We might call such a community network a knowledge-building society.

Electronically networked environments expand the possibilities for what such productive, mutually supportive communities can produce. These environments also alter the working dynamics of these communities. We are creating a miniature version of a knowledge-building society, using Computer Supported Intentional Learning Environment (CSILE™) software (see p. 110).

We are carrying out this work as part of the Canada-wide TeleLearning Network of Centres of Excellence.[1] Our project is distinctive from the many devoted to educational uses of network technology, however. Our own aim is to enhance knowledge building and understanding in all sectors simultaneously, with particular emphasis on K–12 education.

LINKING "SOCIETY" MEMBERS

The network we are creating in Toronto brings together a diverse group of participants. It includes elementary and high school students and their parents, and postsecondary teacher education and medical school students, all of whom can be doing coursework; museum staff, who are planning exhibits; engineering firm staff, who are tackling design problems; and staff from a science center and an art gallery. Also participating will be project researchers and software developers, who will be interpreting what is happening

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CSILE Software: Passport to the Knowledge Society

CSILE™ (Computer Supported Intentional Learning Environment) has been under development since 1986 by a team of cognitive research and computer scientists in Toronto, and teachers across North America. It is the first network system to provide general support for collaborative learning and inquiry in school environments. As such, it is the beacon technology for the K–12 sector of Canada's TeleLearning Research Network. CSILE has been used successfully at all educational levels from the 1st grade to university, in all areas of the curriculum, and with many different kinds of student populations.

At the system's core is a community database, constructured by the users. Items in CSILE's shared work space are called *notes.* Notes may include text, graphics, and links to other media. All notes can be read by all users, but edited only according to set rules. Users create notes or comment on another note, in which case the original author is notified and can immediately view the comments and respond to them. Participants can link notes to any organizational framework created with the CSILE graphics program, thus producing high-level visualizations of work on a particular problem or issue. They can also create special-purpose discussions or conference notes.

Users access CSILE on locally networked or remotely connected computers. (WebCSILE uses a web browser in lieu of client software.) The typical school installation consists of eight computers in each classroom, attached via a local area network to a CSILE server, which maintains the shared workspace.

As links among notes emerge, participants begin to recognize higher-order concepts and view the accumulating knowledge and ways of synthesizing it. In the business world, Lotus Notes is the prime example of such an approach, and is being widely adopted by businesses setting out to become "learning organizations." In the education world, CSILE is the prime example, antedating Lotus Notes by several years.[1]

The CSILE network system is based on a decade of basic and applied cognitive research. Controlled studies show that students who use CSILE excel in a number of areas. They do better on standardized language and reading tests and are better able to comprehend difficult informative texts. They demonstrate advantages in the quality of the questions they ask, their portfolio commentaries and general depth of explanation, and their facility with graphics. They even demonstrate more mature beliefs about learning. The studies show, too, that students at the high and low ends of ability spectrums are equally engaged, and typical gender biases have not appeared.[1]

For further information, visit the CSILE web site at http://www.csile.oise.on.ca.

[1] M. Scardamalia, C. Bereiter, R. S. McLean, J. Swallow, and E. Woodruff, (1989), "Computer-Supported Intentional Learning Environments," *Journal of Educational Computing Research* 5: 51–68.

throughout the network and improving the technological infrastructure to support increasingly effective interactions.

Each of these groups carries out its own work. The work takes the form of entries stored in CSILE databases. Parts of this multimedia database can be closed off as private; but as much as possible, each database is open to people in other parts of the Knowledge Society network. The different open databases are listed, and can be visited, much as one visits web sites on the Internet.

The typical school installation consists of eight computers in each classroom, attached via a local area network to a CSILE server.

Students and other network members can do more than merely visit various databases, however. They can become actively involved, entering text and graphic notes or comments in all content areas. They also may use information they see to create links between notes on different databases, pointing out discrepant information or contributing new information or ideas. (Notification systems inform participants of activity related to the ideas they have contributed.)

A group of 5th and 6th graders, for instance, might be working on the problem "How does electricity work?" At the same time, curators in a science museum might be planning an exhibit on electricity. By visiting the students' databases, the curators will gain an understanding of students' conceptions (and misconceptions) of electricity, and the students will have input to the design of the exhibit.

CSILE also supports other forms of interaction. Participants can perform keyword searches and extend them across databases. Thus, if a student searches by the keyword *electron,* the search would bring together the work of all participants who had assigned this keyword to any note they created. The student could then study, cull, or link the new collection of electron notes, or use it as a basis for forming a new study group. The student could also search by "views," and see that electrons are viewed quite differently by different groups.

It is also possible to organize cross-sector interaction, so that, for example, a medical school class might work with elementary school classes on health-related topics. Other kinds of engagement will be fortuitous, but everyone joining the network is expected to take an interest in, and, where appropriate, make contributions to the work of people in other sectors.

Through a variety of linking, searching, commenting, and visiting activities, the network encourages the formation of new groups and the consideration of ideas from different perspectives. The aim is to enable participants to gain knowledge and understanding and also form important new working relationships, but without being overwhelmed by long lists of notes requiring responses.

CONTRASTING MODELS

To put our Knowledge Society model in perspective, consider two other models for an educational network. In all such models there is a concern for *scalability* (Can small-scale trials go systemwide?) and *sustainability* (Can the model survive without heroic efforts?) Two further issues are whether the model supports a *constructivist approach* to knowledge, and whether it brings about *involvement* of students in the work of the larger society.

> **Model 1. Ask the Expert**
> Volunteer scientists at a petrochemical company agree to answer students' questions about chemical pollutants and additives. Students (or, indirectly, the teacher) submit questions by e-mail. They then share the information they've obtained in class discussions or reports.

This person-to-person approach sometimes works very well. As a model for network use, however, it has three important drawbacks. First, it isn't *scalable*. That is, it may work for a few classrooms, but there aren't enough expert resources to make it work systemwide. Second, it often is not *sustainable*. Typically the relationship is increasingly burdensome for the volunteers. And their initial enthusiasm wanes as they find themselves responding repeatedly to the same questions, or to questions so basic that the students should be able to find answers themselves. (In one case, students became impatient waiting for an e-mail response and so telephoned an expert at work to find out whether a milliliter was a hundredth of a liter or a thousandth!)

Third, this approach goes against *constructivist* principles. It tells students that knowledge is out there in the heads of specialists, not that it is something to be constructed through their own efforts. Finally, although scientists are *involved* in the work of the schools, students are not involved in the work of the scientists. Thus schools continue to be isolated from the workings of a Knowledge Society.

> **Model 2. Cross-School Research Projects**
> Schools in a wide area collaborate on a research project. Designed by the participating teachers or a central organization, the project calls for students to collect data locally, then put what they've found together and draw inferences.

Successful projects of this kind have involved climate, dialect differences, and even the design of a space colony. Unlike Model 1, this model has the virtue of supporting *constructivist* principles. When well organized, such projects have proved to be *sustainable*—typically lasting for three to nine weeks. They are, however, significantly limited in their *scalability.*

Only certain topics lend themselves readily to this approach, and they often require considerable advance organization in order to succeed.

Thus, Model 2 is likely to remain a model for special purposes, not for achieving the core objectives of a subject-matter curriculum. Finally, although cross-school research projects do much to break down the barriers among schools, they maintain the isolation of schools from other sectors of a Knowledge Society, and thus fail the *involvement* criterion.

Students can do more than merely contact people outside the school; they gain entry into their working worlds.

ENGAGING THE LARGER SOCIETY

Our new Knowledge Society model allows for the person-to-person relationships of Model 1 and the distributed projects of Model 2, but it is not limited to them. It is *constructivist* in a deeper sense: it involves people in the actual work of a society engaged in constructing, using, and improving knowledge. Indeed, this *involvement* is our network's outstanding virtue: Students can do more than merely contact people outside the school; they gain entry into their working worlds.

We cannot be sure how *sustainable* the model will be or how much energy will go into sustaining it. But we believe that, because responsibilities are so widely distributed and participants have so many opportunities to organize their knowledge, our model will not be as vulnerable as others that depend on key players.

As for technical requirements, the Knowledge Society model is best served by network databases that students and other participants build and contribute to, instead of communicating through point-to-point messages. As centers of activity and ideas emerge, participants gain new perspectives on the information. This contrasts with Model 1, which requires only e-mail. Model 2 has worked with e-mail, but Web-based technology offers many advantages for coordinating research inputs.

NEW TEACHERS GIVE-AND-TAKE

At best, technology can facilitate the Knowledge Society model. As in all communication, however, human efforts are the crucial elements. In our networks, preservice teachers play a pivotal role. They are involved in both a learning and teaching capacity. Through contracts with experts in many areas—science, mathematics, history—they stretch their understanding of subject matter while serving as mediators between their students and the experts. They also gain a better understanding of learning in TeleLearning environments. And they engage in virtual practice worldwide.

Preservice teachers use their growing pedagogical expertise to come up with approaches that will be particularly productive for their students. For example, a science teacher might realize that students could learn about endangered species in a more integrated way by organizing their collective notes by phylum. Accordingly, the teacher would enter a diagram of a phylogenetic tree and ask students to link their notes to this tree, as appropriate. The tree now provides a new view of their notes. Two other ways of organizing the same notes are a map organizer and a "Reasons for Endangerment" organizer that students generate.[2] By linking their notes to several integrative frameworks, students come to see their ideas in several contexts, each view revealing a new way to discuss their work.

The scientist whose work is linked may or may not have time to join this new discussion group, but will already have played an important role by demonstrating to students that their work relates to that of a practicing scientist.

A ROLE FOR ACADEMIA

Graduate students in education seminars also have a role to play. They study conceptual change and curriculum development by visiting databases throughout the world in which students are learning about everything from photosynthesis to medieval history. The graduate student not only studies the literature of conceptual change, but also views it in the context of society's expectations, as represented in curriculum guidelines.

For example, one graduate student in physics reviewed a unit on "How Heat Affects Matter," produced by 5th and 6th graders. He noticed a great deal of animistic thinking—that is, students said that molecules were "wanting to escape" from heat, "running to get free," and so forth. The physics student created a view of the database that highlighted the different animistic accounts of molecules, a view that could then be studied by students, teachers, science education students, or any other participants in the network who had obtained permission from the student and teacher to work with their database.

There is strength in diversity as schools, businesses, and cultural institutions share a common medium.

The physics teacher also wrote a scholarly paper on issues of curriculum development and conceptual change, an article that was available, not just to a select group of readers, but to a network of participants worldwide. As a result of this give-and-take, the graduate student said that he himself learned more about matter and molecules.

Undergraduate students provide another resource by using worldwide networks as a new form of field study. Like the graduate student, they could, for example, provide faculty and professional development students with valuable information by constructing views of the database that help to identify misconceptions, highlight promising new directions for research, bring participants from different sites into new working groups, or offer explanations that may be extremely helpful to others.

STRENGTH IN DIVERSITY

A Knowledge Society should favor these kinds of mutually supportive efforts. There is strength in diversity as schools, businesses, and cultural institutions share a common medium. This is true, too, of other kinds of connections. Secondary schools have a stake in the outcomes of elementary education. So why not have the contributions of younger children flowed to secondary or postsecondary students, and from there to teachers and teachers in training, and from any of these contributors to those who formulate curriculum guidelines and standards?

Some might consider this Knowledge Society model impractical. But we must overcome the obstacles for three main reasons. First, the model is inevitable. Ideas and inventions, not labor and manufacturing, are already beginning to rule world economies.

Second, the skills and technology for a Knowledge Society are here, and school networks that run counter to it are likely to be short-lived. These wide-ranging networks cost no more than more limited networks, so there is little reason for schools to confine themselves within more limited technologies or networks of participants.

Finally, this is a model of mutually reinforced high achievement, in which students encounter directly the excitement of working with ideas and advancing knowledge over a lifetime, and feel a part of it.

NOTES

1. For further information, visit http://www.telelearn.ca/telelearn.

2. Examples are from D. R. Ward and E. L. Tiessen, (1994), "(Re)modeling Uses of Multimedia and Hypermedia in Education, Paper presented at the World Conference on Educational Multimedia and Hypermedia (ED-MEDIA94) (Vancouver, British Columbia: Association for the Advancement of Computers in Education).

The Saturn School of Tomorrow

by David A. Bennett and D. Thomas King

In St. Paul, educators took a bold approach to creating a completely transformed school, one where students learn to take responsibility for their own learning.

In the world of schooling, we rarely hear the question *What if?* Powerful new ideas about learning abound, but we are hard pressed to fit them into our time-honored traditional schooling model. Visit virtually any of the nation's 16,000 school districts, and you will likely find that what's happening is what's always happened.

In St. Paul, Minnesota, we have asked—and are answering—the *What if?* question at the Saturn School of Tomorrow. Here's how it began. In early 1986, AFT President Al Shanker visited Minnesota and asked, "Why not a General Motors Saturn plant approach in our schools?" Shanker called for teacher and student empowerment, a site-based management model, new roles for staff members—innovations not unlike the changes taking place in the automobile industry.

We had reflected long and hard about a process for systemic and powerful changes in education. Motivated by Shanker's urging, we felt we were in the right place at the right time to develop a retooled, transformed, completely redesigned school in which virtually every student could and would learn. We responded to Shanker's call by creating what we optimistically named the Saturn School of Tomorrow.

It's one thing to dream and talk about *What if?* visions, but moving them to reality takes another level of complexity and commitment. Educators often introduce a seemingly powerful treatment into their schools while attempting to hold all other variables constant. Too often, afterwards they tell us the treatment produced "no significant differences" in student outcomes. Why? Because the

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chaos of everyday concerns in a school swamps everything else. As Ted Sizer (1983) has suggested, "Things remain the same because it is impossible to change very much without changing most of everything. The result is paralysis." We decided it made more sense to bring together the most powerful set of treatments we could find and try them all in a setting that encourages real change to happen.

PARTNERS FOR CHANGE

Beginning with our initial planning group, teachers were central to this new vision. We worked hard in our district to establish greater rapport with the teachers' bargaining union. Local 28 of the St. Paul American Federation of Teachers was eager to help us become the first district in the nation to plan a transformed school.

Things remain the same because it is impossible to change very much without changing most of everything.

We sought other, key partners for this change: the nearby University of St. Thomas, the largest teacher training institution in the Twin City area; Minnesota Educational Computing Corporation (MECC), the largest K–12 educational software company in the world; Apple Computer, a long-term supporter of innovative technology and ideas in education.

Once the partnership was in place, we then had to move the vision to reality. We met for 18 months and developed a tentative mission statement for Saturn: "To bring together the best of what's known about effective learning research and powerful learning technologies into a restructured, transformed, personalized school setting that employs a Personal Growth Plan for each student, a curriculum for today and tomorrow, and the assumption of learning success for *each* child." We are now two years into our *What if?* quest and are finding as many new questions as answers.

Our pared-down budget and St. Paul's new practice of funding new and different magnet schools as an effective means of voluntary desegregation were two factors that eventually helped us secure unanimous board approach to proceed with Saturn planning. Nevertheless, the board expressed serious concerns about the high front-end costs of the planned high-technology learning environment as well as our intent to pay some talented, year-round, extended-day teachers up to $60,000 per year. Our funding timetable addressed those concerns by demonstrating that projected costs would fall to district average per-capita expenditures within three to five years. We also made it clear to the board that a comprehensive evaluation—one that would examine process, product, and cost-effectiveness factors over a three-year period—would hold this new school to high achievement standards on current measures and encourage meaningful progress toward their value-added standards. This ambitious evaluation component received $90,000 in funding from the Bush Foundation.

BEGINNINGS

In the spring of 1989, the board approved the Saturn project planning model and directed that the school be prepared to open in the fall. A local company specializing in the design of artificial intelligence and expert systems volunteered time and expertise to help our teachers' planning committee design a personalized learning program. It was midsummer before the key teaching positions were developed and staff were hired. Our best efforts to locate an affordable downtown lease for the school, where we could draw on the many learning resources of the city, were met with disappointing delays. While staff, parents, and students earnestly looked for a suitable building to purchase, we decided to open Saturn for the 1989–90 school year in temporary quarters, at the Bridge View School for profoundly physically challenged students. Timelines were extraordinarily tight. The able, supportive administrative team at Bridge View provided a welcome mat and a can-do atmosphere for Saturn. In only a few weeks, we had completed enough details and made enough decisions to begin.

Saturn opened its doors on September 5, 1989. The student body consisted of 162 4th through 6th graders from all over the city, representative of the district's 40 percent ethnic diversity, 15 percent with special education needs, and SRA scores that ranged from the 1st through 12th grade levels. Staff included a part-time principal, the project director, the lead teacher, three associate teachers, and a support staff of a prep time teacher, three educational assistants, three teacher aides, four teacher interns, two long-term, part-time substitute teachers (in lieu of an unfilled teacher generalist position), and a school secretary. The new Saturn educational "planet" was born.

ENCOURAGING SELF-DIRECTED LEARNING

It is only learners, not the learned, who will inherit the future.

Eric Hoffer (1982) reminds us that it is only learners, not the learned, who will inherit the future. And just as there is growing consensus that each individual is ultimately responsible for his or her own health, the Saturn community believes each student must assume responsibility for his or her own learning. Our first year at Saturn has taught us that students, with staff serving as guides, helpers, and managers, can and will do this. It takes time for some students to accept the reality that they are truly in charge of their own education. But it does happen. And parents must be an integral part of that empowering process as well. We tell parents when they consider Saturn as their child's school that we expect a high level of involvement from them. They participate in several reporting conferences during the year, and they assist with budget planning, staff selection, and school governance.

Saturn students design and complete their own Personal Growth Plans—the heart of the Saturn concept—which outline their particular goals in both cognitive and wellness areas. To measure progress students also participate in several individual half-hour conferences during the year with their advisors and their parents. These conferences spark each student's Personal Growth Plan and provide content ideas for the menu of courses we offer to meet student goals and district requirements.

The Personal Growth Plan is our "learning compass" at Saturn. When students and parents meet with advisors, it is the students' responsibility to conduct the conference. They tell us what progress they have made toward the goals we all agreed on. Further, they let us know what new topics of study they want to pursue. We try to let them "Follow your bliss," as we call this student-designed course of study.

Last spring, for example, 35 students, aged 8 to 10, asked us for a course on chemistry. The Science Museum of Minnesota, one of our off-site learning campuses, helped us design an "Introduction to Chemistry Concepts" course using its lab facilities. While we do guide students into choosing the courses that meet district and state goals, it is empowering for them to have a say in what they learn.

If staff can find a way to offer what students want to learn, then we're all happy.

DOING IS LEARNING

The Saturn school community believes that doing is a necessary correlate to thinking. At our grand opening ceremony in January 1990, hundreds of guests stepped through and over dozens of Saturn students sprawled on the floor or over work tables, students who were working together more often than alone. Amidst all this creativity, one 5th grader was busily wiring a small motor to the Lego automobile he had constructed. His 4th grade partner was busy writing the Logo computer program to control the little car. One of the guests—William Norris, former chair and CEO of Control Data Corporation—asked the boy what he was doing. "Why, I'm writing a computer program to make the car start and stop," he said.

If staff can find a way to offer what students want to learn, then we're all happy.

When Norris pressed him further, he explained the various steps of the computer program. Still wearing a puzzled look, Norris asked the student to explain in greater detail. The student turned to his partner and whispered, "Gosh, what's the matter with this guy? He doesn't seem to understand anything about computers?"

Norris just winked at them and said, "Thanks, now I'm beginning to understand!"

What our students learn and do at Saturn becomes a part of their Personal Portfolios of Proficiency (as we have come to call our transformed report cards), which then become a part of their cumulative "School Careerbooks" (Saturn's replacement for the yearbook).

A HIGH-TECH ENVIRONMENT

Saturn is a technology-rich school. It is textbook free. We're trying out comprehensive computer-assisted instructional systems from Integrated Learning Systems (Jostens and CCC, are two we are piloting here), which provide tailored, basic instruction in reading, mathematics, and other basic skill areas. We are exploring the use of videodiscs as an interactive system for presenting high-quality visual information. Students may view videodiscs individually, in small learning groups, or in classroom settings. Videodiscs provide far superior visual and audio information than computers do. Connect a computer to a videodisc system and you have the best of both worlds.

For example, in our Discourse Classrooms, the teacher may show several interesting scenes from a videodisc on carnivorous plants (VideoDiscovery), then stop the system and ask questions to assess students understanding. Instead of raising their hands, students type their responses on a keyboard at their desk. Only the teacher can see their answers on the monitor at the front of the room, and then adjust instruction accordingly.

That Saturn is high-tech is evident when you enter the school, but it is also high-teach and high-touch.

LEARNING FROM EXPERIENCE

That Saturn is high-tech is evident when you enter the school, but it is also high-teach and high-touch. The process approach to writing instruction that saturates the school environment is enhanced by our MacIntosh desktop publishing system. Team learning transforms traditionally competitive activities into cooperative ones. And teachers, with input from students, arrange experiential learning activities that truly take advantage of the school's downtown location and culture.

We are establishing informational and mentorship/apprenticeship activities with the business community for our students. Business people and parents are becoming our experts. One parent hauled in gas tanks and goggles last fall and set up cryogenics demonstration, quick-freezing several samples, to the amazement of students. Parents often help teach classes, sharing their skills and knowledge with us.

Because our students want to be involved, they asked for a "Volunteers in the Community" course, which they helped design. The course requires activities such as helping the profoundly handicapped students at Bridge View School. Students enjoy wheeling these students to their classes, helping them with lunch, reading them stories, or square dancing the wheelchairs. We were concerned that Saturn students might have trouble working with these kids who seem so different. But, instead, they see them as students also able to learn, and they want to help make it happen. They've asked to be bused back now that we've moved to our new downtown site, so they can continue this helping service. Saturn students regularly visit nursing homes and hospitals. And one student even opened her own summer school for preschoolers in her neighborhood. She taught them Spanish and singing and local history.

CREATING NEW MODELS

Changing the order of things is tough work: our school will always be in the process of becoming—we will never consider that we have arrived. It isn't just the hard work of changing—a great deal of energy goes into trying to get others involved. Often, these others turn out to be members of our own management team, your board, your colleagues, who believe that anything we have been doing for a long time must be the right thing to do. Research and development just don't make sense to many of those people because change takes scarce resources away from already bare-boned programs, and few districts have enough dollars to go around.

Yet, to improve, we need to invest money in finding new and better ways. Shanker (February 1990) has proposed that the federal government establish a trust fund, the interest from which could be used to reward those schools and teachers that create effective new models of change. We need this kind of motivation. If change is risky, support is necessary.

One of our students, after presenting the video her learning team had produced about life at Saturn school, exclaimed happily, "There's no place like school!" That's music to any teacher's ears—nothing in our world could be a better accolade. If we are truly committed to engaging each student in learning, then, doubts, dangers, and difficulties aside, we must continue asking *What if?* and find new and better ways for all students to learn.

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It's Elementary!

Internet in a K–5 School

by Susan W. Hixson

Should elementary schools in this country be connected to the Internet and be given the opportunity to reach out and explore the far corners of the globe? That this happened at Carminati Elementary School is the result of a district-wide planning effort involving teachers, the state legislature, the community, and business leaders. While the journey toward Internet connectivity is sometimes long and tedious, our experience has yielded rich rewards for the students and faculty of our small K–5 school in Tempe, Arizona.

HOW IT HAPPENED

Six years ago, Carminati Elementary was a *good* school. It was successfully serving the needs of its students. The Tempe Elementary School District had already developed strategic plans to improve the quality of education for all students throughout the district. It seemed a logical next step for each school to also put together plans for improvement. The Carminati staff began to think about how they could create an *even better* school and provide the best education for every student.

Under the leadership of an innovative principal, teams of teachers applied skills from Total Quality Training to create a framework for change. After the 1989–1990 school year, most of the staff volunteered to return for two days of hard work. They developed a vision statement, and a mission statement, and set many goals. Specific areas of weakness were targeted for improvement, teams were formed and action plans were written. The process of reform and restructuring had begun.

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Later that summer, some Carminati staff attended the Arizona Leadership Academy sponsored by the Arizona State Department of Education, and began to solidify plans for change. At the same time, the Arizona Legislature offered grants for school restructuring. Because the groundwork had been done and a plan was in place, Carminati completed an application and was one of the fifteen schools selected. Each school received funds according to its student enrollment. Over a 4-year period, Carminati received $56,000, most of which was dedicated to staff development to support and sustain technological change. Concurrently, the School Governing Board and administration of the Tempe Elementary Schools proposed a $67 million school bond to improve physical facilities. Of that amount, $13 million was earmarked to upgrade district technology. The voters supported this bond issue. Change at Carminati was assured.

Change at Carminati was assured.

THE PLAN UNFOLDS

Soon after the bond initiative, an opportunity for a business partnership developed for Carminati. Motorola Corporation had been working with many schools in the state to support the use of technology to educate children. Because Carminati already had a plan to incorporate technology in the school, the timing was perfect for one of the community's largest employers to join with Carminati to work for Tempe children.

The partnership board of directors established two main goals at Carminati: 1) to foster parent and community involvement and 2) to promote the use of technology at the school. Carminati would become a model for the school district. It was due to the countless hours of technical assistance donated by Motorola and the forward thinking of many interested Tempe citizens that Carminati became the first elementary school in Arizona with a direct connection to the Internet.

This private-public partnership represented a big step forward in a continuing district effort to encourage business involvement in the district. When the Carminati plan to become a model for technology implementation in the district was presented to the Tempe Schools Governing Board, Carminati was moved to the top of the school district priority list. In the fall of 1993, a T1 line was installed. Motorola donated two servers—one for district use and another was placed at Carminati. Motorola engineers designed the layout and plan for the local area network. School district staff arranged Internet access courtesy of Arizona State University. They also installed the necessary wiring and hardware to support the local area network connecting all classrooms in the building. Each classroom was equipped with a telephone, television, and VCR, and the ability to reach laserdisc players and the satellite access in the Media Center by remote control. A schoolwide voice mail system was installed. And, in December 1993, the Carminati Internet connection was officially established.

Carminati became the first elementary school in Arizona with a direct connection to the Internet.

Although the bond issue guidelines had stipulated the purchase of one computer for every three teachers, Carminati asked the School Board for an exception to pilot, the effect of which was having a computer on every classroom teacher's desk. Because of a price reduction at the time the purchase order was placed, we procured additional Macintosh computers. Equipping each classroom teacher with a networked computer is a productive model that will eventually be implemented throughout the district. The networked classroom computers also enable teachers to share two laser printers, access the Internet, and keep in closer contact with parents via the voice mail system. In one two-week period, 175 parents were called by teachers, and this in a school with a population of 380 students!

TECHNICAL SUPPORT AND STAFF DEVELOPMENT

Most school district employees who work in technical services are familiar with computers, tape recorders, and video cameras, but they have never been trained to install network systems or to connect routers to a global network. Formal training is needed to provide district staff with the necessary skills for continued technical support. Presently, Motorola is supplying technical support for the server at Carminati, and district technical support persons are learning to cope with many challenges. But, because of the limitations on the ways bond money can be spent, priorities must be changed within our school system to support new equipment purchased.

Just as students need time to become comfortable and competent with any new skill, teachers must be introduced, convinced, and inserviced in the advantages of using a new tool to enhance a job they already do quite well. In the fall of 1993, Arizona State University helped us get started. Doctoral students shared their ideas with us and introduced us to the mechanics of logging in and traveling around cyberspace. This workshop proved important as it encouraged teachers to begin personal learning. The presentation also represented an important first step in forming a strong and continuing relationship with the Department of Education at ASU.

From Tempe, students can "stand" in the Louvre and look at classic artwork.

Ongoing assistance has been provided by an ASU graduate student who visits Carminati to help with project plans and technical problems. In May 1994, still more ASU graduate students returned to demonstrate Mosaic to all teachers. Our resident doctoral student has constructed a Carminati home page, which will point to the many World-Wide Web resources of interest to Carminati teachers and students. Mosaic enables us to take "virtual field trips," something that may change the way many subjects are taught. From Tempe, students can "stand" in the Louver and look at classic artwork or "walk" through the botanical gardens in Missouri or Australia and compare what they see with their own desert landscape.

DEVELOPING IN-HOUSE EXPERTISE

While support from outside sources is, and has been, wonderful, it is imperative that Carminati staff begin to develop in-house expertise. Initially, a few of the teachers were fascinated and began to read about Internet projects developed by other teachers. I subscribe to a computer service at home and spend countless hours roaming the Internet to find resources appropriate to the Carminati curriculum. Several ways of sharing my constant Internet research have evolved.

On the weekends, I compiled a weekly newsletter to share project ideas and Internet addresses of user-friendly resources. I have also developed three lists of Internet resources. Posted on the server, these lists can be sorted by general topics, kinds of access, and the curriculum focus of the information. Teachers can access these lists from their classroom personal computers:

- One list describes bulletin boards and educational destinations for gopher and telnet access. Teachers are encouraged to try out some of the resources and apply for passwords. Some staff found Newton and Big Sky to be exceptionally user-friendly and began to establish routines of checking for mail and reading postings to learn what was new.
- Another list describes telecommunication projects. It can be sorted by teacher name, state or country, grade level, interests, and addresses. As the staff begin to create projects, they can use this list to send notices to individual teachers interested in similar projects. I find this information from the many postings I read in Kidsphere and other LISTSERVs.
- The third list contains the URL addresses of specific World-Wide Web locations with descriptions of what is available and how this information might be used within the existing Carminati curriculum. The list can be sorted by general curriculum focus and specific topic. Once teachers use an address and find it helpful they can add it to their "hotlist." Then the long and sometimes tricky URL addresses do not need to be retyped.

POTPOURRI OF INTERNET PROJECTS

Our Internet connection has provided many advantages to teachers and students. On October 21, 1994, the first day that the White House was online with a tour, a class of 2nd graders listened while President Clinton welcomed them to the White House. They traveled through his office, met the first family, including Socks the cat, and signed the guest book. This graphical capability opens the world to early readers, and reinforces a need to continually learn and explore. Interactive access to current newspapers, thousands of pictures, and a growing number of resources, museums, and exhibits, is making a significant difference in the thinking of each teacher and student. No longer will schools be limited by printed library resources or money for field trips. Our campus is expanding to include the world.

Some specific projects completed in the first semester of Internet access include:

- Second graders studying Spanish paired up with a Spanish-speaking class in California. These students shared book talks to encourage reading, and the teachers became friends as they wrote, via the Internet, almost daily to share ideas and successes.

- Third graders asked Newton scientists questions, and marked on a map the locations of all their "keypals." They met interested adults around the country who took a few minutes to respond to questions.
- A fourth-grade class helped a student in Washington state who was writing a report about Arizona. They were excited that someone was interested in their state song and what they wore to school on warm winter days.
- Fourth graders wrote a paragraph in a chain story, which began in Florida and traveled to many different states (and also to Finland) before it was completed. This was a rich opportunity for students to critique the writing of other students and contribute to a story they could share with family and friends. They did just that at a Spring Celebration of Fine Arts, which was held at the school.
- Fifth graders and their teacher developed such a strong friendship with a class in Alaska that the teacher and two of her fellow staff flew to Arizona to spend several days visiting Carminati and sharing ideas. The Alaskan students sent pictures and more letters, which were treasured.
- A third-grade class participated in a timed math contest. They did math problems with a popular AppleIIe program that many schools use. Each student's score was then e-mailed to Academy One. A Carminati student came in third among the world-wide participants. Her success brought out a newspaper reporter and photographer for a feature article, which was picked up in papers throughout the Phoenix area.
- A third-grade teacher and one reading group joined an international project to publish a newspaper with articles about heroes. Thirty classes from around the country and Canada participated in the project. Each class contributed articles to a file. After reading all the articles, each student group selected the most interesting and published their own paper. Copies of the completed papers were mailed to each participating location. The highlight of the project came as the mail arrived, and students located their articles in the class papers printed in Canada and around the country. This project raised local interest. A local newspaper editor visited the class to share with students facts about being a reporter and publisher.

EXPANDING THE COMFORT ZONE

Now in the second school year of Internet access and with the expanded capabilities of Mosaic, teachers continue to explore appropriate Internet activities that will stimulate interest and enhance learning. Carminati began classes in July 1994 as it implemented a year-round calendar. Being the only school in Tempe open in July created new challenges. Teachers found that schools in Australia were willing to "visit" and make plans. Some teachers began to exchange e-mail messages with teachers on vacation.

Becoming educated to the opportunities that abound is a continual process. As teachers take classes, read articles, and participate in telecommunication activities, they continue to learn. Change is frightening. It takes precious time to develop a new comfort zone. All change must be supported by continual education. For teachers to take risks and incorporate new approaches in their busy day, they must feel free and safe to explore new approaches to teaching.

Many questions remain unanswered. We do not yet know how all this information will affect learning. Will test scores improve? How will training be institutionalized? Do we need to control what students see as they travel around cyberspace? If a school administration chooses to make possible this adventure, they must be supportive and willing to learn with students and staff. A team effort can pay off generously with positive educational dividends.

Editor's Note

The ancient Chinese proverb best describes my own progressive education as a teacher: "I hear and I forget, I see and I remember; I do and I understand." When I first began teaching, I mostly lectured to my students, which was directed to their hearing and eventual forgetting (some a lot quicker than others). Being an idealist with pragmatist leanings, I eventually resorted to "showing" my students what I thought they needed to know. As a math teacher, I tried to incorporate films—any good films I could find (there weren't many); I used my overhead projector more (causing some eyes to glaze over); I found a few filmstrips (with limited results); and I even put student work on my opaque projector for class discussion (that actually *was* a good idea, especially when I had the students do their own presenting).

I was getting close. They did remember better when I showed them. It took a few more years to discover the big link to learning: let the students do more of the work. Then let them teach me and one another. I was teaching when the so-called "new math" was introduced (which we never had in our college training). Because I was only a few pages ahead of the students, I could play "dumb" and say, "Let's see if we can figure this problem out together!"

Give your learners license to learn: some direction, the tools and resources they need, the opportunity to plan, cooperate, create, and share—then observe. Wonderful things begin to happen, like the "Eureka!" that Archimedes talked about after stepping into a tub of water and discovering the principle of displacement. It's so rewarding to see the lights go on in the eyes of your students, for them to uncover, to discover, to make it their own. Not all learning can happen this way, but a lot of it can. While technology alone can't make learning success happen, I don't believe it can happen very well unless we give students and teachers the tools they need. Technology is an empowering tool that lets students do and understand.

It is also important to remember that just because you *can* use technology, doesn't necessarily mean you *should*. It's important to make a plan in conjunction with any stakeholders (including students and parents). Then find the resources and funding and secure the needed training to use it well. Finally, frequently report on what's working and what needs working on. You need a *system* to make it all work, one that works for your situation. Each article in this collection provides useful information for building a workable system to make technology work in the classroom.

I hope you will continue to read and think about ways technology can empower your teaching and learning as the twenty-first century approaches, with all its changes, promises, and challenges. It's truly an exciting time to be a teacher . . . and a learner. The secret, if there is one, is to be both. Happy teaching and continued learning!

P.S. Once again, I would enjoy hearing from you (what's working, what you're working on, or just hello). You can e-mail me at: dtking@stthomas.edu.

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---

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---

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Through a partnership with Phi Delta Kappa, IRI/SkyLight offers a Network for site-based systemic change: *The Network of Mindful Schools.* The Network is designed to promote systemic school change as possible and practical when starting with a renewed vision that centers on *what* and *how* each student learns. To help accomplish this goal, Network consultants work with member schools to develop an annual tactical plan and then implement that plan at the classroom level.

---

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There are
one-story intellects,
two-story intellects, and three-story
intellects with skylights. All fact collectors, who have
no aim beyond their facts, are one-story men. Two-story men compare,
reason, generalize, using the labors of the fact collectors as well as their
own. Three-story men idealize, imagine, predict—
their best illumination comes from
above, through the skylight.

—Oliver Wendell
Holmes

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TECHNOLOGY in the CLASSROOM

Learn to think about technology in new and powerful ways! This collection, edited by experienced school technologist Tom King, is a brief compendium of articles that gives readers a vivid sense of the new possibilities in education today. These articles, written by experienced users of education technology, touch on three compelling themes: the growing research supporting the belief that technology in education makes a difference for student learning; innovative ways to use technology in teaching; and firsthand accounts of schools that have successfully implemented technology in their classrooms. These writings cover many specifics, such as student-use issues, the importance of electronic networks to link students around the globe, use of multimedia to improve cognitive development and address multiple intelligences, and the materials and initiative needed to make technology projects happen.

Using technology in education requires schools to rethink traditional learning paradigms and create new metaphors for learning. Through effective use, educators can implement technology in ways that transform classroom learning activities, enhance idea development and individual expression, promote peer collaboration and problem solving, and foster students' unique learning styles. Anyone who reads *Technology in the Classroom: A Collection of Articles* will agree that this is an exciting time to be a student . . . and a teacher.

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